The production performance of Holstein and Fleckvieh x Holstein cows in an intensive feeding system

by

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Thesis presented in partial fulfilment of the requirement for the degree of Master of Science (Animal Sciences) in the Faculty of Agriculture at Stellenbosch University

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Declaration

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Date: March 2016

Abstract

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The aim of the study was to determine the effect of crossbreeding using Fleckvieh sires on Holstein cows on milk production and reproduction parameters, veal and beef production and growth parameters of heifers in an intensive feeding system.

The study was conducted at the Elsenburg Research Farm using Fleckvieh x Holstein (FxH) and Holstein (H) cows, bull calves and heifers. Twenty four heifers from both genotypes were initially sourced from a commercial dairy farm and reared to first calving at Elsenburg. Male and female progeny from these cows were subsequently included in the trial. Holstein cows and heifers were inseminated with H semen and FxH cows and heifers were inseminated with Fleckvieh semen. Similar standard management practices with regards to feeding of dairy cows, heifers and bull calves were followed for both genotypes.

Production parameters, corrected for a 305-day lactation period, did not differ, being 6330±117 vs. 6108±97 kg milk, 252±4.7 vs. 251±3.9 kg fat and 202±3.5 vs. 200±2.9 kg protein for H and FxH cows, respectively. Protein and fat percentages differed between genotypes being 3.20±0.02 vs. 3.3±0.02% and 3.98±0.03 vs. 4.13±0.0.02% for H and FxH cows, respectively. Using a dual-purpose breed in a crossbreeding programme on Holstein cows did not reduce the production performance of crossbred cows.

Some fertility parameters of H vs. FxH cows differed significantly, i.e. the interval from calving to first service being shorter for FxH vs. H cows at 86.2±5.3 vs. 104.7±5.0 days, respectively. However, days open tended to differ between genotypes being 153.1±6.8 and 135.3±7.1 for H and FxH cows, respectively. The number of services per conception did not differ between genotypes being 2.24±0.14 and 2.30±0.15 for H vs. FxH cows, respectively. While more FxH cows conceived within 100 days after calving in comparison to H cows, being 37±6 and 48±6%, respectively, the proportion of cows conceiving within 200 days post partum did not differ between genotypes, being 76±4 and 81±4% for H and FxH cows, respectively. Fertility parameters for H vs. FxH heifers did not differ, i.e. age at first insemination was 15.4±0.30 vs. 15.5±0.33 months, age at conception 17.2±0.35 vs. 17.3±0.34 months and age at first calving 26.4±0.37 vs. 26.5±0.24 months of age, respectively.

The birth weight (BW) of FxH and H heifers did not differ, being 37.7±0.65 vs. 37.4±0.71 kg respectively, while the average daily gain (ADG)(determined with a linear regression fitted to obtain individual ADG's) of FxH heifers was

significantly higher than that of H heifers, being 0.813±0.021 vs. 0.696±0.017 kg/day. However, the live weight, stature, girth circumference and age at first calving of heifers did not differ between genotypes.

Bull calves were divided into four groups, the treatments being genotype (H or FxH) and marketing age, i.e. veal (marketed at a live weight of about 200 kg for a carcass weight not exceeding 100 kg) and as beef marketed as steers at 18 months of age. Veal calves were reared in an intensive feeding system while steers were put on kikuyu pasture. For steers reared to 18 months of age, birth weight (BW), live weight (LW) at 18 months of age and ADG did not differ between H and FxH steers, being 38.3±1.3 and 41.2±1.3 kg, 450±16 and 468±20 kg and 0.741±0.022 and 0.778±0.023 kg per day, respectively. For veal calves, the BW, LW at marketing and ADG did not differ between H and FxH, being 39.6±0.70 and 41.4±0.91 kg, 203±1 and 198±2 kg and 0.929±0.020 and 0.953±0.021 kg, respectively.

In conclusion, with the exception of fat and protein percentages, milk production parameters did not differ between H and FxH cows while some fertility parameters differed between genotypes. Crossbred cows showed a positive internal growth rate of 9.4% while H showed a negative internal herd growth of about 5% over the trial period.

Opsomming

Die produksieprestasie van Holstein- en Fleckvieh x Holsteinkoeie in ‘n intensiewe voedingstelsel

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Die doel van die studie was om die effek van kruisteling met Fleckvieh bulle op Holstein koeie op melkproduksie-eienskappe, reproduksie-eienskappe, kalfsvleis- en beesvleisproduksie en groei-eienskappe van vervangingsverse in ‘n intensiewe voedingstelsel, te bepaal.

Die studie is op die Elsenburg Navorsingsplaas uitgevoer met Fleckvieh x Holstein (FxH) en Holstein (H) koeie, bulkalwers en verse. Die studie is begin met 24 verse van beide genotipes wat vanaf ‘n kommersiële melkprodusent aangekoop is. Die verse is sowat vyf dae na geboorte verkry, na Elsenburg vervoer en daar groot gemaak tot eerste kalwing. Die manlike en vroulike nageslag van dié koeie is hierna in die studie opgeneem en toepaslike data is vervolgens van verse en bulle versamel. Holstein koeie en –verse is met Holstein bulle en FxH-koeie en –verse is met Fleckvieh bulle gedek. Dieselfde bestuurspraktyke is toegepas op diere van die verskillende genotipes en groepe.

Melkproduksieparameters, gekorrigeer vir ‘n 305-dag laktasieperiode, het nie tussen genotipes verskil nie. Die melk-, vet- en proteïenproduksie van H- en FxH-koeie was 6330±117 vs. 6108±97 kg, 252±4.7 vs. 251±3.9 kg and 202±3.5 vs. 200±2.9 kg onderskeidelik. Die proteïen- en vetpersentasie het statisties betekenisvol tussen genotipes verskil, naamlik 3.20±0.02 vs. 3.30±0.02% en 3.98±0.03 vs. 4.13±0.0.02% vir H en FxH-koeie onderskeidelik. Om ‘n dubbeldoelras in ‘n kruistelingsprogram op Holstein koeie te gebruik het dus nie die melkproduksie van koeie benadeel nie.

Sommige vrugbaarheidseienskappe het statisties betekenisvol verskil tussen H- and FxH-koeie, naamlik die periode vanaf kalf tot eerste inseminasie was korter vir FxH-koeie as vir H-koeie (86.2±5.3 vs. 104.7±5.0 dae onderskeidelik). Hierteenoor het die periode van kalf to konsepsie geneig om te verskil tussen die rasse, naamlik 153.1±6.8 and 135.3±7.1 vir H- en FxH-koeie onderskeidelik. Die aantal inseminasies per konsepsie (2.24±0.14 en 2.30±0.15 vir H- en FxH-koeie onderskeidelik) het nie verskil tussen genotipes nie omdat dit meer ‘n aanduiding is van die inseminasievermoë van die insemineerder. Meer FxH- as H-koeie het beset geraak binne 100 dae na kalf, naamlik 37±6 and 48±6% onderskeidelik terwyl die persentasie koeie wat binne 200 dae na kalf beset geraak het, nie tussen genotipes verskil het nie, naamlik 76±4 en 81±4% vir H- en FxH-koeie onderskeidelik. Vrugbaarheidseienskappe van verse het nie betekenisvol tussen genotipes verskil nie. Die ouderdom met eerste inseminasie, ouderdom by konsepsie en ouderdom met eerste kalf was 15.4±0.30 vs. 15.5±0.33 maande, 17.2±0.35 vs. 17.3±0.34 maande en 26.4±0.37 vs. 26.5±0.24 maande vir H- en FxH-verse onderskeidelik.

Die geboortegewig van FxH- en H-verse het nie verskil nie en was 37.7±0.65 vs. 37.4±0.71 kg onderskeidelik. Die gemiddelde daaglikse liggaamsmassatoename van FxH-verse was volgens liniêre regresssievergelykings statisties betekenisvol hoër was dié van H-verse, naamlik 0.813±0.021 vs. 0.696±0.017 kg/dag, onderskeidelik. Hierteenoor het die liggaamsmassa, skouerhoogte, borsomvang en ouderdom by eerste kalf nie tussen genotipes verskil nie.

Bulkawers is in vier groepe verdeel is, naamlik genotipe (H en FxH) en bemarkingsouderdom, naamlik (1) kalfsvleis (bulkalwers is grootgemaak tot 'n liggaamsmassa van sowat 200 kg om 'n karkasmassa te lewer wat nie swaarder is as 100 kg nie) en (2) 18-maande ouderdom vir beesvleisproduksie. Vir kalfsvleisproduksie is bulkalwers intensief grootgemaak terwyl in die beesvleisproduksiestelsel is ossies op kikoejoe-weiding aangehou. Vir ossies wat op 18-maande ouderdom bemark is, is die geboortegewig, liggaamsmassa op 18-maande ouderdom en gemiddelde daaglikse liggaamsmassatoename vir H- en FxH-ossies 38.3±1.3 en 41.2±1.3 kg, 450±16 en 468±20 kg en 0.741±0.022 en 0.778±0.023 kg per dag, onderskeidelik. Die geboortemassa, liggaamsmassa by bemarking en gemiddelde daaglikse liggaamsmassatoename van H- en FxH-bulkalwers wat vir kalfvleis grootgemaak is, het nie betekenisvol tussen genotipes verskil nie en was 39.6±0.70 en 41.4±0.91 kg, 203±1 en 198±2 kg en 0.929±0.020 en 0.953±0.021 kg per dag, onderskeidelik.

Die finale gevolgtrekking van die studie is dat met die uitsondering van die vet- en proteïenpersentasie van melk wat betekenisvol verskil het, het melkproduksie-eienskappe nie tussen H- en FxH-koeie verskil nie. Tesame hiermee het sommige vrugbaarheidseienskappe tussen die twee genotipes verskil. Die FxH-koeie het oor die duur van die ondersoek 'n positiewe interne kuddegroei van 9.4% per jaar getoon terwyl die H-koeie oor dieselfde tyd 'n negatiewe kuddegroei van sowat 5% getoon het. Dit beteken dat die aantal koeie in dié groep verminder het.

Dedication

I hereby dedicate this work to my mother, who is the strongest person I know. She held down a fulltime job as a nurse and raised two independent girls during very difficult times when my father was unable to be home for long periods of time. Here is to the person who loaded two kids, the dog and the cat in the car and drove across the country when her father was ill. Who worked night shift for 9 years, just so she could be home for her kids during the day in case of emergency.

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CHAPTER 1

GENERAL INTRODUCTION

The dairy industry in South Africa is presently in a difficult situation, with more than 40% of dairy farmers having left the industry in the past 18 years (Grobler *et al*., 2008). This decrease in the total number of dairy producers in South Africa is mainly due to increasing input costs on dairy farms and low farm-gate prices paid for milk by processors. However, in contrast to the large decrease in the number of dairy producers in South Africa, total milk production in the country increased (Milk Producers Organisation, 2012). This is primarily due to an increase in the average size of South African dairy herds. Furthermore, the geographical distribution of dairy farming has shifted, with a larger percentage of the total milk production being produced in the coastal areas (Neser, 2005; Gertenbach, 2007; Mkhabela & Mndeme, 2010). This is largely related to the lower cost of milk produced from cultivated pasture (Neser, 2005). There is, however, still a need for the production of fresh milk closer to the high density urban areas, where dairy farming is mostly based on total mixed ration (TMR) systems.

The average milk price for producers has dropped from a high of approximately R4.45 in early 2015 to around R3.80 per litre of milk presently (Milk Producers Organisation, 2015). The difference of 65c per litre of milk has had a major effect on the income of a dairy farm. For this reason it has become important that all income sources should be used optimally while also reducing the cost of milk production. Therefore, greater efficiency, better management, and an attentive eye on the financial bottom line have become essential.

1.1 Justification

One of the ways to decrease production costs could include crossbreeding. Crossbreeding has been found to be financially beneficial in a number of studies (McDowell, 1982; Touchberry, 1992; VanRaden & Sanders, 2003; Del Zotto *et al*., 2009; McAllister, 2002).

Dairy producers have indicated interest in crossbreeding for three very specific reasons (Weigel & Barlass, 2003):

1. Milk pricing structures have changed with a greater emphasis on total fat and protein production, and a decreased emphasis on total milk production (Weigel & Barlass, 2003; Baily, 2005; McAllister, 2002).
2. The Holstein breed is developing a reputation as a breed with problems regarding female fertility, calving ease, health and survival (Weigel & Barlass, 2003; Funk, 2006).
3. Inbreeding levels are increasing rapidly for all the major dairy breeds, and crossbreeding may be an effective option in reducing the impact of inbreeding depression on commercial dairy farms (Weigel & Barlass, 2003; Funk, 2006).

Crossbreeding in the dairy industry could vary from using beef breeds on dairy cows to using dairy breeds. Each combination would have a different outcome. It is to be expected that using beef breeds on dairy cows would result in increasing beef production and possibly better fertility although this would come at the expense of a decreased milk production (Osterhoff & Couvaras, 1978). Crossbreeding between dairy breeds is fairly common specifically with pasture-based systems using Jersey sires on Holstein cows (Muller & Botha, 2008). Dual-purpose breeds have not commonly been used in crossbreeding programmes in the dairy industry.

Specifically to improve the fertility of Holstein cows, crossbreeding studies in the United States of America (USA) used Montbéliarde sires, a Simmental derived dual-purpose breed from France, on Holstein cows. Results were very positive (Heins *et al*., 2007). Fleckvieh is also a Simmental derived breed from Germany, and is characterised as a dual-purpose breed, with medium to high milk yield levels containing high fat and protein percentages, with a high beef potential and good fertility (Muller & Botha, 2008). A number of dairy farmers in the pasture-based areas of South Africa have been doing crossbreeding using Jersey bulls on Holstein cows in a similar way as New Zealand crossbreeding systems. Some farmers were also using Fleckvieh sires on specifically Jersey cows and were keen to get more information on the advantages and problems related to this crossbreeding system (Muller & Botha, 2008).

A companion study on crossbreeding using Fleckvieh sires on Jersey cows has also been conducted at Elsenburg Research Farm, showing higher total milk, fat and protein production, fertility and the growth of veal calves and steers for Fleckvieh x Jersey cows and bull calves in comparison to Jerseys (Goni, 2014).

Using the Fleckvieh breed in a crossbreeding study on H cows should improve their beef production and reproduction through the effect of heterosis, while not reducing the milk production of the crossbred cows significantly.

1.2 Problem statement

Globally, the Holstein dairy breed is experiencing a lower fertility (Heins *et al*., 2006; Heins *et al.* 2007; Clark *et al*., 2007). The same trend is observed locally in the South African dairy industry. This can partly be attributed to selection pressure for high milk production, as there is an antagonistic relationship between milk production traits and fertility (Royal *et al*., 2002; Carthy *et al*., 2016). Fertility traits generally have low heritability estimates (Royal *et al*., 2002) which would make it a slow process for a reversal of poor fertility within a breed. Crossbreeding has been suggested as a method of improving the fertility of dairy cows, but the breed used should be chosen carefully not to affect the milk production of cows negatively. The Fleckvieh is a dual-purpose breed with moderate to high milk production levels while maintaining a good fertility performance (Piccand, 2013; Muller & Botha, 2008). The aim of the study was to determine the effect of crossbreeding using Fleckvieh sires on H cows on milk production and reproduction parameters, beef production and growth parameters in an intensive feeding system.

1.3 Study objectives

The present study was conducted to determine the effect of crossbreeding using Fleckvieh sires on H cows concentrating on comparing the production performance of FxH and H cows, heifers, steers and bull calves in an intensive feeding system. The following aspects were compared:

1. milk production characteristics of H and FxH cows,
2. reproductive performance of H and FxH heifers and cows,
3. growth performance of H and FxH heifers, and
4. growth performance of H and FxH bull calves reared for veal or as steers for beef being marketed at 18 months of age.

1.4 References

Anonymous, 2015. Dairy market trends. Publication of the Milk Producer's Organisation. August 2015.

Baily, K.W., Jones, C.M. & Heinrichs, A.J., 2005. Economic returns to Holstein and Jersey herds under multiple component pricing. J. Dairy Sci. 88: 2269 – 2280.

Carthy, T.R., Ryan, D.P., Fitzgerald, A.M., Evans, R.D. & Berry, D.P., 2016. Genetic relationships between detailed reproductive traits and performance traits in Holstein-Friesian dairy cattle. J. Dairy Sci. 99: 1286 – 1297.

Clark, D.A., Caradus, J.R., Monaghan, R.M., Sharp, P. & Thorold, B.S., 2007. Issues and options for future dairy farming in New Zealand. New Zealand J. of Agric. Res. 50(2): 203 – 221.

Del Zotto, R., Penasa, M., De Marchi, M., Cassandro, M. & Lopez-Villalobos, N., 2009. Use of crossbreeding with beef bulls in dairy herds: Effect on age, body weight, price, and market value of calves sold at livestock auctions. J. Anim. Sci. 87: 3053 – 3059.

Funk, D.A., 2006. Major advances in globalization and consolidation of the artificial insemination industry. J. Dairy Sci. 89: 1362 – 1368.

Gertenbach, W., 2007. Dairy farming in South Africa – where to now? Institute for Animal Production. Department of Agriculture. pp 1 – 7.

Goni, S., 2014. Production and reproduction performance of Jersey and Fleckvieh x Jersey cows in a pasture-based system. MSc(Agric) Thesis, University of Stellenbosch, Stellenbosch, South Africa.

Grobler, S.M., Scholtz, M.M., Bester, J., Mamabolo, J.M. & Ramsay, K.A., 2008. Dairy production systems in the emerging and communal sectors of South Africa: Results from a structured survey. Appl. Anim. Husb. & Rural Develop. 1: 25 – 30.

Heins, B.J., Hansen, L.B. & Seykora, A.J., 2006. Fertility and survival of pure Holsteins versus crossbreds with Holstein and Normande, Montbéliarde and Scandinavian Red. J. Dairy Sci. 89: 4944 – 4951.

Heins, B.J., Hansen, L.B. & Seykora, A.J., 2007. The California experience of mating Holstein cows to A.I. sires from the Swedish Red, Norwegian Red, Montbéliarde, and Normande breeds. University of Minnesota report on research. pp. 1 - 18

McAllister, A.J., 2002. Is crossbreeding the answer to the question of dairy breed utilisation? J. Dairy Sci. 85: 2352 – 2357.

McDowell, R.E., 1982. Crossbreeding as a system of mating for dairy production. Southern Cooperative Series Bulletin No. 259. Louisiana Agricultural Experimental Station, Baton Rouge, LA.

Mkhabela, T. & Mndeme, S.H., 2010. The cost of producing milk in the KwaZulu-Natal Midlands of South Africa: A cost curve approach. Agrekon. 49(1): 122 – 142.

Muller, C.J.C. & Botha, J.A., 2008. Preliminary results on crossbreeding Jerseys with Fleckvieh sires. Elsenburg Journaal: 2008(1): 2 – 3.

Neser, F.W.C., 2005. The use of crossbreeding in dairy cattle in South Africa. Fleckvieh World. 2005. pp. 4 – 5.

Osterhof, D.R. & Couvaras, S., 1978. Is beef production from South African dairy herds possible? J. SA Vet. Assoc. 49(1): 15 – 18.

Piccand, V., Cutullic, E., Meier, S., Schori, F., Kunz, P.L., Roche, J.R. & Thomet, P., 2013. Production and reproduction of Fleckvieh, Brown Swiss, and 2 strains of Holstein-Friesian cows in a pasture-based, seasonal-calving dairy system. J. Dairy Sci. 96: 5352 – 5363.

Royal, M.D., Pryce, J.E., Woolliams, J.A.F., 2002. The genetic relationship between commencement of luteal activity and calving interval, body condition score, production, and linear type traits in Holstein-Friesian cattle. J. Dairy Sci. 85: 3071 – 3080.

Touchberry, R.W., 1992. Crossbreeding effects in dairy cattle: the Illinois experiment, 1949 – 1969. J. Dairy Sci. 75(2): 640 – 667.

VanRaden, P.M., & Sanders, A.H., 2003. Economic merit of crossbred and purebred US dairy cattle. J. Dairy Sci. 86: 1036 – 1044.

Weigel, K.A. & Barlass, K.A., 2003. Results of a producer survey regarding crossbreeding on US Dairy farms. J. Dairy Sci. 86: 4148 – 4154.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

According to McAllister (2002), Jay L. Lush (1994) stated in “Genetics of populations” that “the demonstrated commercial success of hybrid corn and hybrid chicks has made it seem biologically possible to make several new breeds, each good in some specific combinations although its own average phenotypic merit may only be mediocre. Using these breeds in rotational crossbreeding plans might be more profitable for commercial production than would raising any pure-breds which are available. This has been successful with chickens and (to a lesser extent) with pigs. Could it be extended profitably to other species which are less prolific and have longer generation intervals?”

This level of using hybrid power has mostly not been used in dairy cattle, possibly because of their much longer generation interval than is the case for chickens and pigs, which has the implication that progress is slower. Dairy breed societies are generally not in favour of crossbreeding using either another other dairy breed or a dual-purpose breed and would prefer recommending using strategies like out-crossing or other breeding methods to limit inbreeding and to “fix” poor traits like fertility in the specific breed (H. Duvenhage, 2016, Personal communication, Breed Director, SA Holstein Breed Society, Bloemfontein, South Africa).

Earlier studies have indicated that crossbreeding in dairy cattle could be useful, i.e. McDowell (1982) concluded that “crossbreds may not exceed the best purebred for any single trait, yet the net economic merit of crossbreds may be superior to purebreds when all traits affecting and influencing net income are considered”. Later, Touchberry (1992) concluded from the results of a crossbreeding study that was conducted from 1949 to 1969 in Illinois, United States of America (USA) using Holsteins and Guernseys, that crossbreeding has merit due to a 14.9% increase in income per lactation. Although the results from this study may not be directly related to modern-day dairy cows, the results from this study created a growing interest in present day crossbreeding studies (Heins *et al*., 2006[a]). VanRaden & Sanders (2003) also noted that interest in crossbreeding was increasing while some countries using pasture-based systems, like New Zealand, have a large prevalence for crossbreeding with crossbred cows making up about 35% in all cows in milk recording.

One the major reasons for considering crossbreeding in Holsteins is the level of inbreeding being experienced in the breed, especially in the USA. However, according to Heins *et al.* (2007) this growing problem of inbreeding in the Holstein breed is not isolated to the USA population, but is a global problem. When evaluating bulls being used, Heins *et al.* (2007) found that Interbull evaluations showed that the same sires of sons are being used by A.I. organisations throughout the world. The result of importing foreign semen from different countries (and South Africa is not isolated from this trend), is that very little so-called “outcross” Holstein genetics currently exist globally (Heins *et al.* 2007).

2.1.1 Inbreeding in the Holstein breed.

According to Falconer (1989), inbreeding results when the dam and sire of the calf has some level of relationship due to shared ancestry. This increases the incidence of similar genes being carried over from both parents. This fact has been used in linebreeding to increase the incidence of desired traits, but the converse is also true as it could lead to an increase in the expression of genetic recessive genes, some of which has highly negative effects on functional traits (Heins *et al*., 2007).

Falconer (1989) summarised the effects of inbreeding as follows:

- loss of genetic variability.
- increased incidence of detrimental recessive genes in the homozygous state and
- inbreeding depression.

It has been a widely held belief by many dairy farmers that due to the popularity of the Holstein breed worldwide, the size of the gene pool protects the Holstein breed from a high level of inbreeding. This does not seem to be the case as Heins *et al*. (2007) indicated that the average pedigree inbreeding level of Holstein females in the USA has rapidly increased in the past few years, from 2.8% in 1991 to 5.3% in 2006. This increase has been attributed to the extensive use of a few selected individuals or cow families (Weigel, 2001). This has resulted in economic losses due to inbreeding depression on production, growth, health and fertility (Weigel, 2001).

Increases in inbreeding in dairy breeds has been reported worldwide, with studies done in the United Kingdom (UK) (Kearny *et al*., 2004), South Africa (Maiwashe *et al*., 2006,), Denmark (Sørensen *et al*., 2005), United States of America (USA) (Hansen, 2000; Young & Seykora, 1996; Smith *et al*., 1998, Adamec *et al*., 2006), Germany (Koenig & Simianer, 2006), Canada (Miglior & Burnside, 1995), USA and Canada (VanRaden, 1992), Ireland (McParland *et al*., 2007), Spain (González-Recio *et al*., 2007), Iran (Rokouei *et al*., 2010), Australia (Man *et al*., 2002) and New Zealand (Clark *et al*., 2007) all indicating varying degrees of inbreeding within the Holstein breed.

The average inbreeding levels for South African Holsteins were estimated to be 2.30% in 2003, with an annual rate of inbreeding estimated to be 0.06% (Maiwashe *et al*. 2006). The maximum inbreeding coefficient for SA Holsteins was however reported as 37.5% (Maiwashe *et al*. 2006). The effective population size of the South African Holstein breed (which gives an estimate of the genetic variability of the population) was estimated to be 137 animals by Maiwashe *et al*. (2006), which is more positive than the low population size of 39 reported by Weigel (2001) for the USA population.

Extensive use of specific bulls can, however, increase the likelihood of the later generations having a higher incidence of familial connections due to the unequal genetic contribution to the next generation, and would, therefore, decrease the effective population size.

According to Heins *et al.* (2007) the greatest problem with inbreeding, as perceived by dairy producers, is an increase in the number of stillbirths, reduced cow fertility, lower disease resistance and shortened herd life. A list of references from the available literature on the regression of productive and functional traits on a 1% increase in inbreeding is presented in Table 2.1 (Koenig & Simianer, 2006).

Table 2.1 The effect of a 1% increase in inbreeding on productive and functional traits in different dairy breeds (SCS = Somatic cell score)

Traits	**Breed**	**Country**	**Regression per 1% of inbreeding**	**Reference**
Calving interval	Holstein	Canada	+0.2 days	Hodges *et al*., 1979
		USA	+0.1 days	Hudson & Van Vleck, 1984
Days open	Holstein	USA	+0.13 days	Hoechele, 1991
Service period	Holstein	USA	+0.11 days	Hoechele, 1991
305-day milk yield	Jersey	Canada	- 26.7 kg	Miglior *et al*., 1992
		USA	- 21.3 kg	Wiggans *et al*., 1995
	Brown Swiss	Switzerland	- 28.0 kg	Casanova *et al*., 1992
		USA	- 24.6 kg	Wiggans *et al*., 1995
	Holstein	USA	- 22.6 kg	Short *et al*., 1992
			- 29.6 kg	Wiggans *et al*., 1995
			-26.7 kg	Smith *et al*., 1998
			- 52 kg	Thompson *et al., 2000*
305-day fat yield	Jersey	Canada	- 0.6 kg	Miglior *et al*., 1992
		USA	- 1.0 kg	Wiggans *et al*., 1995
	Brown Swiss	Switzerland	- 0.1 kg	Casanova *et al*., 1992
		USA	-1.1 kg	Wiggans *et al*., 1995
	Holstein	USA	- 0.8 kg	Short *et al*., 1992
			- 1.1 kg	Wiggans *et al*., 1995
			- 0.9 kg	Smith *et al*., 1998
Fat %	Jersey	Canada	- 0.0028%	Miglior *et al*., 1992
	Brown Swiss	Switzerland	- 0.0005%	Casanova *et al*., 1992
305-day protein yield	Jersey	USA	- 0.8 kg	Wiggans *et al*., 1995
	Brown Swiss	USA	- 0.9 kg	Wiggans *et al*., 1995
	Holstein	USA	- 0.9 kg	Short *et al*., 1992
			- 0.9 kg	Wiggans *et al*., 1995
SCS	Holstein	Canada	+0.0012	Miglior *et al*., 1995
		USA	+ 0.002	Smith *et al*., 1998
			0.0	Thompson *et al., 2000*
Productive life	Holstein	USA	- 5.9 days	Smith *et al*., 1998

The results in Table 2.1 demonstrates a wide range of negative effects on production parameters and functional traits attributed to a 1% increase in inbreeding percentage, which would have the consequence of a reduced financial viability for a dairy enterprise.

Thompson *et al*. (2000) indicated that with the high rate of inbreeding globally, producers are finding it difficult to choose bulls that would not contribute to increased inbreeding in their herds. The negative effect of inbreeding could be even more negative on the financial health of a dairy farm due to the negative effect it has on the survival of the cows in the herd, than the effect it has on the easily measured production parameters (Thompson *et al*., 2000).

As most of the semen imported into South Africa for use with the current generation of Holstein cattle are from the USA (Mostert & van der Westhuizen, 2015[b]), there is a high probability that inbreeding in the South African Holstein herd has increased above the 2.30% estimated by Maiwashe *et al. (2006)*, due to the average inbreeding level in the USA Holstein herd being above 5% (Heins *et al*., 2007).

Due to fertility and longevity problems in the breed, the South African total merit index (HMI) has recently been developed putting more (38%) emphasis on health and fertility traits, 45% on production traits and only 17% on conformation traits (Mostert & van der Westhuizen, 2015[a]).

The Holstein breed has mainly been selected for high milk production, and functional traits have been neglected. This has led to a dairy breed with the highest milk production of all the dairy breeds, while also experiencing problems with fertility and longevity (Ferris *et al*., 2014).

Ferris *et al*. (2014) grouped the possible solutions to the fertility and longevity problems found in dairy cattle in three strategies:

1. improved within-breed selection programmes,
2. using an alternative breed on the farm to replace the Holsteins or
3. doing crossbreeding.

2.1.2 Merits of crossbreeding

Crossbreeding has two potential advantages: breed complementarity and heterosis or hybrid vigour. Breed complementarity is defined as the introduction of favourable genes from a different breed, where such genes may have been completely absent or present at a very low frequency in the recipient breed (Maltecca *et al*., 2006). Heterosis can be described as the enhanced performance of crossbred animals, relative to the average of the parent breeds. This enhanced performance is usually greater than the average calculated if only the two breeds' respective performances are considered. Heterosis results from increased heterozygosity while alleviating inbreeding depression which creates or maintains genetic interactions causing hybrid vigour (Maltecca *et al*., 2006, VanRaden & Sanders, 2003).

The change in milk pricing methods, with greater emphasis on high fat and protein percentages, as well as concerns about the health, fertility and calving performance of purebred Holsteins, have stimulated some dairy producers' interest in crossbreeding (Maltecca *et al*., 2006). Increased fat and protein yields by crossbred cows have been demonstrated in a number of studies (Ahlborn-Breier & Hokenboken, 1991; Lopez-Villalobos & Garrick, 2002; Goni, 2014; VanRaden & Sanders, 2003; Heins *et al*., 2006[b]). Maltecca *et al*. (2006) stated that heterosis effects in crossbred animals are usually noticeable in traits related to health and fertility.

Lopez-Villalobos *et al*. (2000[a]) concluded that rotational crossbreeding could increase the profitability of dairy farming under New Zealand conditions. Beginning with a Jersey (J) herd, cows were mated to Holstein (H) bulls to produce F_1 HxJ cows. Half of the F_1 cows were mated by Holstein bulls to produce 75% H cows, and the other half were mated by Jersey bulls to produce 75% J cows. Subsequently the 75% H cows were mated to J bulls and the 75% J cows were mated to H bulls. After three generations, half of the herd was 67% H + 33% J and the other half of the herd was 33% H + 67% J. Lopez-Villalobos *et al*. (2000[a]) indicated that this strategy maintained 67% of the heterosis expressed by the F_1. Similarly in this trial, starting with a Holstein (H) herd, and applying crossbreeding using Fleckvieh (F) sires, it should be possible to maintain a herd where approximately half the herd consist of about 67% F + 33% H cows and the other half of the herd is about 33% F + 67% H cows.

Lopez-Villalobos & Garrick (2002) demonstrated the benefits of heterosis, with three scenarios being considered for crossbreeding Holstein and Jersey cows:

- Scenario I: Ignoring the effect of heterosis.
- Scenario II: Heterosis for production.
- Scenario III: Heterosis for production and longevity.

Heterosis for production traits in Scenario II led to the crossbred cows ranking higher than H and J for fat production (kg/year), although for protein production (kg/year) crossbred cows only ranked higher than J cows (Table 2.2). When heterosis for longevity was included in Scenario III, this led to a reduced replacement rate, with the net effect being an older herd (more mature cows), with higher milk, fat and protein yields per cow for crossbred cows. Even in Scenario III, crossbred cows did not exceed the milk production of the purebred Holstein cows, although fat and protein yields were higher.

Table 2.2 The productive performance of pure-bred and crossbred dairy herds under different scenarios for heterosis (Lopez-Villalobos & Garrick, 2002)

Parameters	Purebreds		Scenario I		Scenario II		Scenario III	
	F	J	F_1 FxJ	Rt FxJ	F_1 FxJ	Rt FxJ	F_1 FxJ	Rt FxJ
Live weight, kg	447	353	400	400	407	405	410	406
Production per cow								
Milk (liters/year)	3770	2768	3269	3269	3396	3354	3427	3370
Fat (kg/year)	165	160	162	162	169	167	171	168
Protein (kg/year)	131	112	122	122	126	125	127	125
DM requirements (kg/year)	5006	4209	4607	4607	4728	4688	4568	4591
Stocking rate (cows/ha)	2.40	2.86	2.61	2.61	2.54	2.56	2.63	2.61
Production per hectare								
Milk (liters/year)	9036	7890	8514	8514	8620	8586	9002	8808
Fat (kg/year)	395	455	422	422	430	428	449	439
Protein (kg/year)	313	321	316	316	321	319	334	327
Replacement rate (%)	22.0	22.0	22.0	22.0	22.0	22.0	17.8	19.6
Average herd age (years)	4.48	4.48	4.48	4.48	4.48	4.48	5.09	4.89

F = Holstein-Friesian, J = Jersey, F_1 FxJ = first cross, Rt F x J = rotational cross; Scenario I: ignoring heterosis; Scenario II: heterosis for production; and Scenario III: heterosis for production and longevity.
DM = Dry Matter.

Lopez-Villalobos *et al*. (2000[a]) further suggested that the breeding programme used in New Zealand with purebred cattle in the progeny testing schemes does have the potential to increase the size of active cow populations while maintaining high selection intensities. This is also important as crossbreeding still requires a pool of purebred bulls of high genetic merit. There must, therefore, be a compromise between using crossbreeding and maintaining a large purebred herd for the maintenance of the breed's genetic merit.

Alternative breeds for crossbreeding could also be considered. In California seven large dairies decided to mate Holstein Heifers and cows with imported semen of the Normande and Montbéliarde breeds from France, as well as the Swedish Red and Norwegian Red breeds (reported in the data as Scandinavian Red) (Heins *et al*., 2007). Other breeds used were Ayrshire, Brown Swiss, Guernsey, Jersey and Milking Shorthorn (VanRaden & Sanders, 2003).

The Montbéliarde is a French Simmental derived dual-purpose breed, while the Fleckvieh is a German Simmental derived dual-purpose dairy breed. The Fleckvieh dual-purpose breed is one of the major breeds in worldwide milk production (Edel *et al*., 2011) The Fleckvieh is a true dual-purpose breed with high milk yields and good milk quality traits, but is also used primarily for beef in some countries (Grogan *et al*., 2005). This makes the Fleckvieh breed an ideal candidate for use in crossbreeding with other dairy breeds such as the Holstein.

2.1.3 The effect of crossbreeding on milk production

For commercial dairy producers crossbreeding has been a way to improve protein and fat production in dairy cows (VanRaden & Sanders, 2003). In that study the most popular breed for backcrossing was the Holsteins, with cows mainly being backcrossed with Ayrshire, Brown Swiss, Guernsey, Jersey and the Milking Shorthorn. VanRaden & Sanders (2003) reported that although the protein production of Brown Swiss x Holstein cows did not differ (P>0.05) from purebred Holsteins, fat production for crossbred cows was higher than that of purebred cows. This resulted in the crossbred cows showing a financial advantage in comparison to Holstein cows (VanRaden & Sanders, 2003).

Dillon *et al*. (2003) reported that in Ireland, the practice of mainly selecting for increased milk production has been put into question by three important developments in the industry. Firstly, the introduction of milk quotas in Europe, secondly, the negative effect of selecting for higher milk yield levels on the fertility of dairy cows and thirdly the change in the way how dairy farmers were paid for their milk, i.e. moving away from a purely volume-based price and more towards a component-based price determination.

According to Heins *et al*. (2006[b]) purebred Holstein cows produced more (P<0.01) milk and total protein than Normande x Holstein, Montbéliarde x Holstein and Scandinavian Red x Holstein cows, being 9757±102, 8530±90, 9161±77 and 9281±77 kg milk and 305±3, 277±3, 293±2 and 297±2 kg protein, respectively. However, although the total fat production of Holstein cows did not differ (P>0.05) from that of Scandinavian Red x Holstein cows, being 346±4 and 340±3 kg, total fat production was higher (P<0.05) than for the Normande x Holstein and Montbéliarde x Holstein at 319±3 and 334±3, respectively. Both the Normande x Holstein and Montbéliarde x Holstein cows produced less (P<0.01) total fat plus protein, being 596±6 and 627±5 vs. 651±6 and 637±5 than both the purebred Holsteins and the Scandinavian Red crossbreds.

Heins *et al*. (2007) demonstrated that the milk, fat and protein production of Normande x Holstein, Montbéliarde x Holstein and Scandinavian Red x Holstein cows differed (P<0.01) from that of Holstein cows. The biggest increase in milk production occurred from first to second lactation, but the total amounts of milk, fat and protein was -9%, -5% and -3% less than that of the Holstein in the first lactation and -12%, -7% and -6% in the second lactation of that of the pure Holstein cows for the Normande x Holstein, Montbéliarde x Holstein and the Scandinavian-Red x Holstein, respectively.

The New Zealand dairy farming industry is unique in that crossbreeding has been used fairly extensively since the 1960's, giving Ahlborn-Breier & Hohenboken (1991) the opportunity to evaluate crossbred cattle vs. purebred cattle in a commercial setting. They reported a higher (P<0.001) fat production for F1 Holstein and Jersey crossbred cows compared to purebred Holstein cows, indicating that this result were not isolated to research herds but was replicated on commercial farms.

According to Vance *et al*. (2012), in a crossbreeding trial with Jerseys and Holstein-Friesians, the milk production of purebred animals was higher (P<0.01), but the milk of crossbred cattle had higher (P<0.01) fat and protein percentages. Vance *et al*. (2012) found that while the somatic cell count of pure- and crossbred cows differed in absolute terms, differences were not significant (P>0.05).

2.1.4 The effect of crossbreeding on reproduction

Royal *et al*. (2000); Lucy (2001); Liu *et al*. (2008); Sun *et al*. (2010) and Sewalem *et al*. (2010) showed a decreased fertility in Holstein cattle, which is mainly attributed to a change in reproductive physiology of dairy cows from around the 1950's till 2001, partly explained by physiological adaptations to high milk production (Lucy, 2001), though increased milk production is not the only factor affecting reproduction in the dairy cow (Lucy, 2001; Carthy *et al*., 2016). By using a model developed by Maas *et al*. (2009), it was illustrated that the sustainability of the United Kingdom national Holstein herd is not possible. This is mainly attributed to prolonged calving intervals and a general lack of an adequate number of replacement heifers. Haile-Mariam *et al*. (2013) stated that "one of the reasons for the decline in fertility of dairy cows is the unfavourable genetic correlation between milk yield traits and fertility and intense selection for increased milk yield".

Lower fertility in Holstein cows had a negative effect on profitability and this effect is twice as high in seasonal-calving herds as in herds that calve down year-round (Haile-Mariam, 2013). This is mainly due to cows not becoming pregnant having to be culled or a late calving resulting in short lactation periods (Clark *et al*., 2007). Commercial dairy producers indicated that crossbred cows achieved higher conception rates than purebred Holstein cows (Weigel & Barlass, 2003).

The international dairy industry is concerned about the decline in Holstein fertility (Heins *et al*., 2006[c]; Clark *et al*., 2007). This decline is probably because of a combination of physiological and management factors. Lucy (2001) found that higher milk production levels, larger herds, reduced cow health and increased inbreeding may have contributed to the reproductive decline in the Holstein breed. Heins *et al*. (2006[c]) cited a number of sources that substantiate the claim that there is an increase in the intervals for days to first breeding and days open in Holstein cows therefore extending calving intervals.

According to Heins *et al*. (2006[c]) studies suggest that the possible advantages of crossbred over purebred cows lie in a shorter breeding period, fewer days open, a larger proportion of cows completing more than one lactation and a higher percentage of cows that conceive during any breeding period.

Heins *et al*. (2007) found that between 15% and 19% more ($P<0.05$) crossbred cows calved a second time within 14 months of first calving when compared to purebred Holsteins. This statistical difference still remained after 20 months from first calving, though the percentage was lower to 8% vs. 14% of the purebred Holsteins. Heins *et al*. (2006[c]) reported that the interval from calving to first breeding was less ($P<0.05$) for Normande x Holstein and Montbéliarde x Holstein cows being 62 days and 65 days, respectively, in comparison to 69 days for purebred Holsteins. The first service conception rate of the Normande x Holstein and Montbéliarde x Holstein ($P<0.01$) was higher ($P<0.05$) at 35% and 31% respectively, compared to 22% for the purebred Holsteins (Heins *et al*., 2006[c]). All crossbred cows had fewer ($P<0.05$) days open than purebred Holsteins, least square means being 150±4, 123±4, 131±4 and 129±5 days for purebred Holsteins, Normande x Holstein, Montbéliarde x Holstein and Scandinavian Red x Holstein cows respectively.

Ferris *et al*. (2014) reported on a crossbreeding trial in the USA using Normande, Montbéliarde, Swedish Red, Norwegian Red and Jersey A.I. sires on Holstein cows, showing shorter intervals from calving to conception (days open) and improved survival of the crossbred cattle vs. purebred Holsteins, with little reduction in production. Ferris *et al*. (2014) also found that, specifically the Montbéliarde and the Scandinavian Red crossbreds were more profitable than the purebred Holstein cows.

Heins *et al*. (2008[b]) reported that crossbred cows had fewer days open (P<0.01) than purebred Holstein cows, being 127 vs. 150 days, respectively. A greater proportion of crossbred cows were pregnant (P<0.05) at 150 and 180 days after calving than purebred cows, being 75 vs. 59% and 77 vs. 61%, respectively.

Williams (2007) found that purebred Holstein cows took longer (P<0.05) to start cycling after calving than Jersey x Holstein and Jersey cows. Holstein cows had lower (P<0.05) first service conception rates and 90 days pregnancy rates than the crossbred cattle.

Makgahlela *et al*. (2008) indicated that the calving interval in the South African Holsteins had increased from 386 days in 1984 to 412 days in 2004. Obviously the fertility traits of South African Holstein cows seem to be regressing. Global dairy breeders are also concerned about fertility in Holstein herds and crossbreeding is becoming a more attractive solution (Funk, 2006).

Heins *et al*. (2006[a]) found that all crossbred cows (Normande x Holstein, Montbéliarde x Holstein and Scandinavian-Red x Holstein) had fewer cases of calving difficulty at first calving (P<0.05) than purebred Holstein cows (3.7 to 11.6 % vs. 17.7%). Heins *et al*. (2006[a]) also found that Montbéliarde x Holstein and Scandinavian Red x Holstein had lower (P<0.01) stillbirth rates than purebred Holstein cows at 6.2 and 5.1% vs. 14%, respectively. Calving difficulty is a significant problem in a dairy herd, as it causes trauma for the cow and calf often leading to stillbirths and reduced milk production and ultimately lower health in cows.

2.1.5 Effect of crossbreeding in feed efficiency

According to Heins *et al*. (2008[a]) the feed efficiency of Jersey x Holstein cows did not differ (P>0.05) from Holstein cows, despite Jersey x Holstein cows having lower (P<0.01) live weights and higher (P<0.05) body condition scores than purebred Holstein cows. This was mainly due to the fact that the dry matter intake of the crossbred cows did not differ (P>0.05) from that of the purebred cows when based on percentage of body weight (4.7% vs. 4.5 %). There is contradictory literature in this regard, with most studies finding that body weight is often lower in Jersey x Holstein cattle (Auldist *et al*., 2007; Vance *et al*., 2012), but that the crossbred cows often have higher body condition scores than the purebred cows (Auldist *et al*., 2007; Vance *et al*., 2012). Depending on the breed used in the crossbreeding trials, some studies found that crossbred cows had similar feed efficiencies to purebred Holsteins, notably the study by Heins *et al*. (2008[a]) and Wang *et al*. (1992). Schwager-Suter *et al*. (2001) found that F_1 crossbred Holstein x Jersey cows were more feed efficient than purebred Holstein and Jersey cows.

2.1.6 Effect of crossbreeding on longevity

Lopez-Villalobos *et al*. (2000[a]) observed that the replacement rates was lower for crossbred herds than for purebred herds, indicating that crossbred herds had more animals available for sale and that fewer replacements were required to replace culled cows. The proportion of mature cows in crossbred herds were higher than what was found in purebred herds, which resulted in higher overall yields for milk, fat and protein, mainly due to the fact that the milk production of cows in later lactations is generally higher than younger cows (Lopez-Villalobos *et al*., 2000[a]).

Weigel & Barlass (2003) stated that Brown Swiss x Holstein and Jersey x Holstein crossbred cows had an advantage with regards to longevity in comparison to purebred Holstein cows. VanRaden & Sanders (2003) established that the mean productive life of first generation (F1) crosses vs. purebred Holsteins, evaluated over a period of 32 years, were 24.3 months compared to 23.8 months (P<0.0001), with a very small heterosis estimate of 1.2%. Productive Life (PL) was calculated as total months of milk production limited to 10 months per lactation and seven years of age.

Heins *et al*. (2007) also found that the survival rates of the Holsteins and Normande x Holstein, Montbéliarde x Holstein and Scandinavian Red x Holstein cows differed (P<0.01), with pure Holsteins culled or dead earlier than all crossbred groups of cows, with 83% of purebred Holsteins surviving 305 days post-calving compared to 90% to 93% for crossbred cows.

Heins *et al*. (2012) found that all crossbred groups in their study had more (P<0.01) cows that calved down multiple times. The mean survival period for crossbred cows was 300 to 400 days longer (P<0.01) than for purebred Holstein cows. When lifetime production of fat plus protein was considered, the crossbred cows again out-performed the purebred Holstein cows (P<0.01).

McAllister *et al*. (1994) reported an estimate of heterosis for lifetime profitability of approximately 20%.

Weigel & Barlass (2003) indicated improved survivability of F1 Holstein x Jersey calves, relative to purebred Holstein calves. This was confirmed by Maltecca *et al*. (2006) who showed that Holstein calves were more susceptible to perinatal mortality than calves from crossbred sires (P<0.05). Pre-weaning mortality of female calves in the study was also higher (P<0.05) for Holstein heifers in comparison to heifers from crossbred sires (Maltecca *et al*., 2006).

2.1.7 Crossbreeding implications for the management of dairy herds.

Kargo *et al*. (2012) indicated that crossbreeding could be used successfully at all management levels, and not just in low management herds. The high (36%) percentage of crossbred dairy cows in New Zealand corroborates this, as acquired from data of New Zealand Dairy statistics 2009 – 2010 from the Livestock improvement Cooperation of New Zealand and DairyNZ (Kargo *et al*., 2012).

Ericson *et al*. (1998) concluded in a review of the available literature on crossbreeding dairy cows, that one of the prerequisites for a successful crossbreeding program is that two breeds of similar performance should be used, as this is the only time when crossbreeding is a realistic alternative for all dairy farmers.

2.2 Overview of the current dairy situation in South Africa

The dairy industry is progressively concentrating in the coastal areas with the geographical distribution changes driven by the potential to produce pasture on a year-round basis (Coetzee, 2012, Mkhabela & Mndeme, 2010). The exception to this is large dairies being operated close to high density urban areas as there is a saving in the transport cost of milk to processing plants. Dairy farms are also growing in size in areas close to large rivers or abundant water resources.

As can be seen in Table 2.3, the dairy industry in South Africa has also contracted over the last few years (Mkhabela & Mndeme, 2010).

Table 2.3. The change in the number of dairy farmers per province from 1997 to 2008

Province	Number of dairy farmers per year					Change (%) 1997-2008
	1997	2003	2006	2007	2008	
Western Cape	1577	973	878	827	815	-48.3
Eastern Cape	717	481	422	420	407	-43.2
Northern Cape	133	67	39	37	34	-74.4
KwaZulu-Natal	648	449	402	385	373	-42.4
Free State	1204	1250	1067	987	919	-23.7
Northwest	1502	819	649	596	549	-63.4
Gauteng	356	282	275	245	228	-36
Mpumalanga	866	477	407	357	302	-56.1
Northern Province	74	58	45	45	38	-48.1
Total	7916	4856	4184	3899	3665	-48.2

Despite the decrease in the number of dairy farmers, the trend in total milk production in South Africa is positive (Coetzee, 2012). The annual raw milk purchases has increased from 2 303 000 tonnes in 2004 to 2 983 000 tonnes in 2014 (Coetzee, 2015).

The lack of decrease in milk production can be attributed to an increase in producers with bigger herds, contributing a larger proportion of the total milk production. The average dairy herd increased by 25 cows from 2009 to 2012 (Coetzee, 2015). The number of recorded herds in the milk recording scheme has decreased from 1489 herds in 2001 to 560 in 2011, while the number of cows per recorded herd has increased from 78 cows in 2001 to 209 in 2011 (ICAR, 2011).

Milk production in South Africa also has a strong seasonal pattern, with the most milk usually being produced during the summer months from September to January (Coetzee, 2012).

The dairy farming industry also varies across regions. There are definite differences, depending on the resources available to the farmers. Commercial dairy production systems in South Africa can be divided into total mixed ration (TMR), pasture-based and partially pasture-based systems. The pasture-based systems enjoy a financial advantage, and are mainly based in the Southern Cape, KwaZulu-Natal and the Coastal Eastern Cape. This is mostly because of a high regular rainfall in these areas, with the implication that these farmers need less irrigation for cultivated pastures. Total mixed ration systems are mainly used in the Western Cape region, as well as on the Highveld and Free State regions. The highest concentration of the TMR systems is in areas close to high densities urban areas, in the central part of the country and in the areas of high grain production (Gertenbach, 2007). This is, however, not a hard and fast rule, as there are farms using TMR systems in the mainly pasture-based areas, as well as pasture-based systems in the mainly TMR areas, especially along major water sources, which enables dairy farmers to use the water for irrigation of pastures. Partially pasture-based systems can be found in both areas (Gertenbach, 2007; Coetzee, 2012).

2.3 Conclusion

Crossbreeding has been suggested as a solution to a range of problems experienced with the Holstein breed. Decreased fertility and longevity in the breed are traits that have their roots in the increased inbreeding percentage of the Holstein breed worldwide. Crossbreeding would decrease the likelihood of recessive genes being expressed in dairy cattle, by utilising another unrelated breed to the Holstein and, therefore, decreasing the likelihood of the offspring receiving two copies of the same recessive gene. Crossbreeding also has the potential for heterosis, especially in traits related to health and fertility. Literature has also indicated that crossbreeding has led to dairy herds with a higher percentage of mature cows, which is an indication of longevity improvement. The Fleckvieh is a Simmental derived dual purpose Dairy breed with good fertility characteristics, which could lead to increased heterosis or complementarity, especially with low heritable traits like longevity.

2.4 References

Adamec, V., Cassell, E.P., Smith E.P. & Pearson, R.E., 2006. Effects of inbreeding in the dam on dystocia and stillbirths in US Holsteins. J. Dairy Sci. 89: 307 – 314.

Ahlborn-Breier, G. & Hohenboken, W.D., 1991. Additive and non-additive genetic effects on milk production in dairy cattle: evidence of major individual heterosis. J. Dairy Sci. 74: 592 – 602.

Anonymous, 2011. Yearly survey on cow milk recording, years 2010 to 2011. Available at WW.ICRA.ORG/Publications/Biennial statistics of cow milk, sheep milk and beef recording. Publication of the International Committee for Animal Recording. Accessed on 4 February 2016.

Auldist, M.J., Pyman, M.F.S., Grainger, C. & Macmillan, K.L., 2007. Comparative reproductive performance and early lactation productivity of Jersey x Holstein cows in predominantly Holstein herds in pasture-based dairying system. J. Dairy Sci. 90: 4856 – 4862.

Carthy, T.R., Ryan, D.P., Fitzgerald, A.M., Evans, R.D. & Berry, D.P., 2016. Genetic relationships between detailed reproductive traits and performance traits in Holstein-Friesian dairy cattle. J. Dairy Sci. 99: 1286 – 1297.

Clark, D.A., Caradus, J.R., Monaghan, R.M., Sharp, P. & Thorold, B.S., 2007. Issues and options for future dairy farming in New Zealand. New Zealand J. of Agric. Res. 50(2): 203 – 221.

Coetzee, K., 2015. Lacto data Statistics. 18(1): 16 – 23.

Coetzee, K., 2012. The South Africa dairy industry. World Dairy Summit 2012: A world in one country. Cape Town, South Africa.

Dillon, P., Buckley, F., Conner, P.O., Hegarty, D. & Rath, M., 2003. A comparison of different dairy cow breeds on a seasonal grass-based system of milk production. 1. Milk production, live weight, body condition score and dry matter intake. Livest. Prod. Sci. 25: 21 – 33.

Edel, C., Schwarzenbacher, H., Hamann, H., Neuner, S., Emmerling, R. & Götz, K.U., 2011. The German-Austrian genomic evaluation system for Fleckvieh (Simmental) cattle. Interbull bulletin 44: 152 – 156.

Ericson, K., Danell, B. & Rendell, J., 1998. Crossbreeding effects between two Swedish dairy breeds for production traits. Livest. Prod. Sci. 20: 175 – 192.

Falconer, D.S., 1989. Introduction to Quantitative Genetics. John Wiley & Sons, Inc., New York, NY.

Ferris, C.P., Heins, B.J. & Buckley, F., 2014. Crossbreeding in dairy cattle: Pros and Cons. WCDS Advances in Dairy Technology 26: 223 – 243.

Funk, D.A., 2006. Major advances in globalization and consolidation of the artificial insemination industry. J. Dairy Sci. 89: 1362 – 1368.

Gertenbach, W.D., 2005. Breeds of dairy cattle. KZN Department of Agriculture and Rural Development, Cedara. Accessed at Kzndae.gov.za on 12 December 2015.

Gertenbach, W., 2007. Dairy farming in South Africa – Where to now? Institute for Animal Production, Western Cape Department of Agriculture. pp.1 – 7.

Goni, S., 2014. Production and reproduction performance of Jersey and Fleckvieh x Jersey cows in a pasture-based system. MSc (Agric) Thesis, University of Stellenbosch, Stellenbosch, South Africa.

González-Recio, O., López de Maturana, E. & Gutiérrez, J.P., 2007. Inbreeding depression on female fertility and calving ease in Spanish Dairy cattle. J. Dairy Sci. 90(12): 5744 – 5752.

Grogan A., Wickham, B., Olori, V. & Cromie, A., 2005. Strategies for European Fleckvieh cattle breeding to optimize dual-purpose breeding particularly for beef production. Stočarstvo 59(5): 339.

Haile-Mariam, M., Bowman P.J. & Pryce, J.E., 2013. Genetic analyses of fertility and predictor traits in Holstein herds with low and high mean calving intervals and in Jersey herds. J. Dairy Sci. 96: 655 – 667.

Hansen, L.B., 2000. Consequences of selection for milk yield from a geneticist's viewpoint. J. Dairy Sci. 83: 1145 – 1150.

Heins, B.J., Hansen, L.B. & Seykora, A.J., 2006[a]. Calving difficulty and stillbirths of pure Holsteins versus crossbreds of Holstein with Normande, Montbéliarde and Scandinavian Red. J. Dairy Sci. 89: 2805 – 2810.

Heins, B.J., Hansen, L.B. & Seykora, A.J., 2006[b]. Production of pure Holsteins versus crossbreds of Holstein with Normande, Montbéliarde and Scandinavian Red. J. Dairy Sci. 89: 2799 – 2804.

Heins, B.J., Hansen, L.B. & Seykora, A.J., 2006[c]. Fertility and survival of pure Holsteins versus crossbreds with Holstein and Normande, Montbéliarde and Scandinavian Red. J. Dairy Sci. 89: 4944 – 4951.

Heins, B.J., Hansen, L.B. & Seykora, A.J., 2007. The California experience of mating Holstein cows to A.I. sires from the Swedish Red, Norwegian Red, Montbéliarde, and Normande breeds. University of Minnesota. Report on research. pp. 1 - 18

Heins, B.J., Hansen, L.B. & Seykora, A.J., Hazel, A.R., Johnson, D.G., & Linn, J.G., 2008[a]. Crossbreds of Jersey x Holstein compared with pure Holsteins for body weight, body condition score, dry matter intake, and feed efficiency during the first one hundred fifty days of first lactation. J. Dairy Sci. 91: 3716 – 3722.

Heins, B.J., Hansen, L.B., Seykora, A.J., Johnson, D.G., Linn J.G., Romano, J.E. & Hazel, A.R., 2008[b]. Crossbreds of Jersey x Holstein compared with pure Holsteins for production, fertility, and body and udder measurements during first lactation. J. Dairy Sci. 91: 1270 – 1278.

Heins, B.J., Hansen, L.B. & de Vries, A., 2012. Survival, lifetime production, and profitability of Normande x Holstein, Montbéliarde x Holstein, and Scandinavian Red x Holstein crossbreds versus pure Holsteins. J. Dairy Sci. 95: 1011 – 1021.

Kargo, M., Madsen, P. & Norberg, E., 2012. *Short communication*: Is crossbreeding only beneficial in herds with low management level? J. Dairy Sci. 95: 925 – 928.

Kearny, J.F., Wall, E., Villanueva, B. & Coffey, M.P., 2004. Inbreeding trends and application of optimised selection in the UK Holstein population. J. Dairy Sci. 87(10): 3503 – 3509.

Koenig, S. & Simianer, H., 2006. Approaches to the management of inbreeding and relationship in the German Holstein dairy cattle population. Livest. Prod. Sci. 103. 40 – 53.

Lopez-Villalobos, N. & Garrick, D.J., 2002. Economic heterosis and breed complementarity for dairy cattle in New Zealand. 7th World Congr. Genet. Appl. Livest. Prod. Montpellier, France.

Lopez-Villalobos, N. Garrick, D.J., Blair, H.T. & Holmes, C.W. 2000[b]. Possible effects of 25 years of selection and crossbreeding on the genetic merit and productivity of New Zealand dairy cattle. J. Dairy Sci. 83: 154 – 163.

Lopez-Villalobos, N. Garrick, D.J., Holmes, C.W., Blair, H.T. & Spelman, R.J., 2000[a]. Profitability of some mating systems for dairy herds in New Zealand. J. Dairy Sci. 83: 144 – 153.

Lush, J., 1994. The genetics of populations. Special report Nr. 94. Iowa State University, Ames. Iowa. USA.

Lucy, M.C., 2001. Reproductive loss in high-producing dairy cattle: where will it end? J. Dairy Sci. 84: 1277 – 1293.

Lui, Z., Jaitner, J., Reinhardt, F., Pasman , E., Rensing, S. & Reents, R., 2008. Genetic evaluation of fertility trait of dairy cattle using a multiple-trait animal model. J. Dairy Sci. 91: 4333 – 4343.

Maas, J.A., Garnsworthy, P.C. & Flint, A.P.F., 2009. Modeling responses to nutritional, endocrine and genetic strategies to increase fertility in the UK dairy herd. Vet. J. 180: 356 – 362.

Makgahlela, M.L., Banga, C.B., Norris, D., Dzama, K. & Ng'ambi, J.W., 2008. Genetic analysis of age at first calving and calving interval in South African Holstein cattle. Asian J. Anim. Vet. Adv. 3: 197 – 205.

Maiwashe, A., Nephawe, K.A., van der Westhuzen, R.R., Mostert, B.E. & Theron, H.E., 2006. Rate of inbreeding and effective population size in four major South African dairy cattle breeds. S. Afr. J. Anim. Sci. 36(1): 50 – 57.

Maltecca, C., Khatib, H., Schutzkus, V.R., Hoffman, P.C. & Weigel, K.A., 2006. Changes in conception rate, calving performance, and calf health and survival from the use of crossbred Jersey x Holstein sires as mates for Holstein dams. J. Dairy Sci. 89: 2747 – 2754.

Man, W.Y.N., James, J.W. & Nicholas, F.W., 2002. Effect of inbreeding contribution from particular ancestors: a preliminary analysis of first lactation milk yields from Holstein Friesians in Australia. Proc. 7th World Congr.Genet. Appl. Livest. Prod., Montpellier, France. Session 23. pp 1 – 4.

McAllister, A.J., Lee, A.J., Batra, T.R., Lin, C.Y., Roy, G.L., Vesely, J.A., Wauthy, J.M. & Winter, K.A., 1994. The influence of additive and non-additive gene action on lifetime yields and profitability of dairy cattle. J. Dairy Sci. 77(8): 2400 – 2414.

McAllister, A.J., 2002. Is crossbreeding the answer to the question of dairy breed utilisation? J. Dairy Sci. 85: 2352 – 2357.

McParland, S., Kearny, J.F., Rath, M. & Berry, D.P., 2007. Inbreeding effects on milk production, calving performance, fertility, and conformation in Irish Holstein-Friesians. J. Dairy Sci. 90: 4411 – 4419.

Miglior, F. & Burnside, E.B., 1995. Inbreeding in Canadian Holstein cattle. J. Dairy Sci. 78: 1163 – 1167.

Mkhabela, T. & Mndeme, S.H., 2010. The cost of producing milk in the KwaZulu-Natal Midlands of South Africa: A cost curve approach. Agrekon. 49(1): 122 – 142.

Mostert, B.E. & van der Westhuizen, J., 2015[a]. The sense in having a national genetic evaluation in the genomic era. SA Holstein Newsletter. August 2015. pp 12 – 19.

Mostert, B.E. & van der Westhuizen, J., 2015[b]. Genetic levels of global Holstein populations. SA Holstein Newsletter. August 2015. pp 20 – 25.

Royal, M.D., Darwash, A.O., Flint, A.P.F., Webb, R., Woolliams, J.A. & Lamming, G.E., 2000. Declining fertility in dairy cattle: Changes in traditional and endocrine parameters of fertility. Anim. Sci. 70: 487 -501.

Rokouei, M., Vaez Torshizi, R., Moradi Shahrbabak, M., Sargolzaei, M. & Sørensen, A.C., 2010. Monitoring inbreeding trends and inbreeding depression for economically important traits of Holstein cattle in Iran. J. Dairy Sci. 93 (7): 3294 – 3302.

Schwager-Suter, R., Stricker, C., Erdin, D. & Kunzi, N., 2001. Net efficiencies of Holstein, Jersey and F1-crosses. Anim. Sc. 72: 335 – 342.

Sewalum, A., Kistemaker, G.J. & Miglior, F., 2010. Relationship between female fertility and production traits in Canadian Holsteins, J. Dairy Sci. 93: 4427 – 4434.

Smith, L.A., Cassell, B.G. & Pearson, R.E. 1998. The effects of inbreeding on the lifetime performance of dairy cattle. J. Dairy Sci. 81: 2729 – 2737.

Sørensen, A.C., Sørensen, M.K. & Berg, P. 2005 Inbreeding in Danish cattle breeds. J. Dairy Sci. 88(5): 1865 – 1872.

Sun, C., Madsen, O., Lund, M.S., Zhang, Y., Nielsen, U.S. & Su, G., 2010. Improvement in genetic evaluation of female fertility in dairy cattle using multiple-trait models including milk production traits. J. Anim. Sci. 88: 871 – 878.

Thompson, J.R., Everett, R.W. & Hammerschmidt, N.L., 2000. Effects of inbreeding on Production and Survival in Holsteins. J. Dairy Sci. 83: 1856 – 1864.

Touchberry, R.W., 1992. Crossbreeding effects in dairy cattle: the Illinois experiment, 1949 – 1969. J. Dairy Sci. 75(2): 640 – 667.

Vance, E.R., Ferris, C.P., Elliott, C.T., McGettrick, S.A. & Kilpatrick, D.J., 2012. Food intake, milk production, and tissue changes of Holstein-Friesian and Jersey x Holstein-Friesian dairy cows within a medium-input grazing system and high-input total confinement system. J. Dairy Sci. 95: 1547 – 1544.

VanRaden, P.M., 1992. Accounting for inbreeding and crossbreeding in genetic evaluation of large populations. J. Dairy Sci. 75(11): 3136 – 3144.

VanRaden, P.M. & Sanders, A.H., 2003. Economic merit of crossbred and purebred US dairy cattle. J. Dairy Sci. 86: 1036 – 1044.

Wang, S., Roy, G.L., Lee, A.J., McAllister, A.J., Lin, C.Y., Vesley, J.A., Wauthy, J.M. & Winter, K.A., 1992. Evaluation of various measures of and factors influencing feed efficiency of dairy cattle. J. Dairy Sci. 75(5): 1273 – 1280.

Weigel, K.A., 2001. Controlling inbreeding in modern breeding programmes. J. Dairy Sci. 84 (E Suppl.): E177 – E184.

Weigel, K.A. & Barlass, K.A., 2003. Results of a producer survey regarding crossbreeding on US dairy farms. J. Dairy Sci. 86: 4148 – 4154.

Williams, C.M., 2007. Effects of crossbreeding on puberty, postpartum cyclicity and fertility in pasture-based dairy cattle. MSc thesis. North Carolina State University. Raleigh, North Carolina.

Young, C.W. & Seykora, A.J., 1996 Estimates of inbreeding and relationship among registered Holstein females in the United States. J. Dairy Sci. 79(3): 502 – 505.

CHAPTER 3

The milk production and milk composition of Holstein and Fleckvieh x Holstein cows in a total mixed ration system

Abstract

Dairy producers are finding dairy farming challenging due to high input costs and low farm gate milk prices. A major constraint is the longevity of dairy cows mainly because of poor fertility. Crossbreeding is currently being considered as an option to overcome poor fertility in dairy cows. The Fleckvieh dual-purpose breed is a Simmental derived breed from Germany with medium to high milk and fertility characteristics. In this study the milk production performance of 150 Holstein (H) and 139 Fleckvieh x Holstein (FxH) cows in a total mixed ration feeding system was compared. Cows were fed a total mixed ration in dry lots and were milked twice a day. Milk, fat and protein production, fat and protein percentages were determined over consecutive lactation periods according to standard milk recording procedures. Production parameters corrected for a 305-day lactation period did not differ (P>0.05) between genotypes, being 6330±117 vs. 6108±97 kg milk, 252±4.7 vs. 251±3.9 kg fat, 202±3.5 vs. 200±2.9 kg protein for H and FxH cows, respectively. Fat and protein percentages differed (P<0.05) between genotypes, being 3.98±0.03 vs. 4.13±0.02% and 3.20±0.02 vs. 3.30±0.02 for H and FxH cows, respectively. Using a dual-purpose breed in a crossbreeding programme on Holsteins did not reduce the milk yield of crossbred cows. Generally results agree with research conducted in the USA also showing no differences in milk yield parameters between Montbéliarde x Holstein in comparison to Holstein cows.

3.1 Introduction

The primary product on a dairy farm is milk, and therefore, factors affecting the production and value per litre of milk are of paramount importance for dairy farmers. The income derived from milk sold to dairy processors is affected by the quantity and quality of milk produced. The quality of the milk is affected by the nutrition of the cow (Mackle *et* al., 1999; Palmquist *et al*., 1993) and health status of the cow (Lievaart *et al*., 2005) as well as the hygiene of the milk harvesting and storage process in the dairy itself (Lievaart *et al*., 2005). The quantity of milk production as well as milk composition is affected by the breed of the cow (Palmquist *et al*., 1993), but there are also variations among cows on an individual basis within breeds and due to the age of cows (Palmquist *et al*., 1993). Apart from genetics, the milk composition can also be affected by environmental factors such as the interval between milkings, stage of lactation (Mackle *et* al., 1999; Palmquist *et al*., 1993), the quality of the diet the cows received (especially the roughage fraction) (Mackle *et* al., 1999) and season (Mostert *et al.*, 2001; Palmquist *et al*., 1993).

Dechow *et al*. (2007) determined the heterosis effects for fat yield and protein yield in Brown Swiss x Holstein F1 crosses. However, disappointing results were found in subsequent generations, which they equated to possible recombination losses in Holsteins. A severe decline in cow fertility has encouraged many producers to resort to rely heavy on hormone therapy to establish pregnancy (Caraviello *et al*., 2006 as cited by Dechow *et al*., 2007) at a time when consumers are increasingly concerned about the use of hormones in animal production.

Muller *et al*. (2009) found that the total milk produced, fat yield or protein yield of H and FxH cows did not differ (P>0.05), although fat and protein percentages differed (P<0.05). No information is available in the literature on the lactation curves for Fleckvieh or similar type breeds. According to Mostert *et al*. (2003) the lactation curve for milk yield of first lactation Holstein cows in the South Africa national data set showed an increase from the start of the lactation to 60 to 70 days post calving, after which milk yield declines towards the end of the lactation. First lactation Jersey cows show a downward trend in milk yield from the first test to the end of lactation.

Goni (2014) found significant differences (P<0.05) between all the 305-day milk production parameters for Jersey and Fleckvieh x Jersey cows. While Fleckvieh x Jersey cows produced more (P<0.05) milk, fat and protein, fat and protein percentages were higher (P<0.05) in Jersey milk in comparison to Fleckvieh x Jersey milk.

Some South African dairy farmers, mostly pasture-based, have been applying crossbreeding for a number of years. However, this was without any local scientific support. Crossbreeding programmes were based mostly on New Zealand systems although production systems are not similar in these two countries (Muller & Botha, 2008). Farmer crossbreeding programmes provide mostly anecdotal results as few participate in milk recording. Except for the crossbreeding studies at Elsenburg two crossbreeding studies have been conducted in South Africa aimed at producing cows that could produce milk from natural grazing for resource poor farmers. The studies were conducted at Makhathini Research Station (Oosthuizen, *et al*., 2015) and Glen Agricultural Institute (L. Burger, 2016, Personal communication, Department of Agriculture, Free State Province, Bloemfontein, South Africa) using indigenous Nguni bulls on Jersey and Holstein cows, respectively. The Nguni breed is an indigenous beef breed capable of producing steers under poor feeding conditions (Oosthuizen, *et al*., 2015). Anecdotal evidence from these trials at both research institutions suggest that Nguni x Jersey and Nguni x Holstein cows did not adapt well to commercial milking procedures, i.e. not showing normal milk let-down reactions. For this reason milk production was poor and not economically viable. The studies were not comparable to commercial farming practices.

The aim of the present study was to compare the milk production performance of H and FxH cows receiving a total mixed ration in an intensive feeding system.

3.2 Materials and methods

3.2.1 Site description:

The trial was conducted at the Elsenburg Research Farm, approximately 16 km from Stellenbosch in the Western Cape Province of South Africa. The farm is located at 33° 50' 33" S and 18° 49' 49" N. The area is characterised by a Mediterranean type climate with cool wet winters and warm dry summers. The long term average rainfall for the Stellenbosch area at different sites varies between about 550 and 960 mm/year (Carey *et* al., 2008). Most rainfall occurs mainly during the winter from May to September.

3.2.2 Experimental animals

The trial was started with 24 H and 24 FxH heifers obtained from a commercial dairy farm. Heifers were collected every second week and all heifers that were at least five days old were included in the trial. At the original farm, colostrum was fed to the calves until five days of age. Calves were transported to Elsenburg and put into individual calf pens. On arrival they received pre-heated colostrum collected from cows that had recently calved in the Elsenburg herd. The calves then received colostrum up to the age of eight days and thereafter full cream milk at 5% of body weight (or approximately two litres of milk at each feeding) twice a day until about six weeks of age. A calf starter meal containing 18% CP was provided *ad libitum* from seven days of age until the calves had a daily intake of 1 kg at about 2 months of age. After this period, a growth meal containing 15% CP was provided according to NRC (2001) guidelines until 6 months of age. From six months of age a growth meal containing 15% CP was provided until the calves were approximately 12 months old. The heifers were then put on kikuyu pasture, and supplemented at two kg per heifer per day with a growth meal containing 15% CP until calving.

All heifers were inseminated at approximately 13 months of age, and if not confirmed pregnant by 15 months of age, they were synchronised to facilitate insemination.

After calving, lactating cows were fed a total mixed ration (TMR) consisting of 70 kg oat hay, 280 kg lucerne hay, 50 kg ground maize, 25 kg soy bean oil cake meal and 575 kg of a commercial concentrate. The diet was mixed in 1000 kg batches and fed to cows twice a day in fence-line feeding troughs. At least 25 kg of the TMR was fed per cow per day. Holstein and FxH cows were kept together in the same group. Cows had free access to the TMR as well clean drinking water.

During the dry period cows of both genotypes were kept on kikuyu pasture. A pasture replacement mixture was fed to cows on a daily basis when pasture was limited. At about three weeks before their expected calving dates, cows were put in a steam-up group being fed the pasture replacement diet and a dry cow concentrate supplement at 1 kg per cow per day. The amount of concentrate was increased by one kg every week until calving after which cows were put on the lactation diet. During the steam-up period dry cows and heifers received 3 to 6 kg of a 15% protein pre-partum meal.

Cows were milked twice daily (6:00 am and 15:00 pm), and the milk yield and milk composition of all pure and crossbred cows was recorded according to standard milk recording procedures. Milk recording dates were provided each year and each individual recording event entailed the recording of the daily (evening and next morning's) milk yields of each cow approximately every five weeks starting from five days after calving to drying up. Cows were dried up at about 60 days before their next expected calving date. Cows were maintained in the herd for as long as possible and were culled for normal reasons, i.e. not becoming pregnant, recurring mastitis, injuries or death. Milk samples were collected at the afternoon milking for each cow and analysed for fat, protein and lactose concentrations using a Multi-spec infra-Red analyser.

All cows were treated the same throughout the trial period.

3.2.3 Data collection

Milk yield and milk composition were obtained from SA Studbook and production records for each lactation period was estimated using the interval (number of days) between milk recording events. Adjusted 305-day lactation records were estimated based on records from at least three milk recording events. Fat and protein production was estimated for each cow. This data was used to estimate a component value for each lactation period using the following equation:

Component Value = ((6 x fat) + (13 x protein)/2

3.2.4 Statistical analysis

The data were analysed using PROC GLM procedures from SAS (2009). The effects of genotype and parity on milk yield, fat yield, protein yield, fat percentage and protein percentage were analysed using ANOVA. Repeated records were considered as uncorrelated to meet the assumptions for ANOVA. Least square means were calculated for each effect, where they separated using PDIFF STDERR of SAS (2009).

The model used was $Y_{ij} = \mu + B_i + P_j + e_{ij}$

where:

Y_{ij} = milk yield, fat yield, protein yield, fat%, protein % (305-day corrected)

μ = population mean

B_i = fixed effect of genotype (I = Holsteins, Fleckvieh x Holsteins)

P_j = fixed effect of parity (j = 1, 2, 3, 4)

e_{ij} = random error

Preliminary analysis included the effect of year of birth and calving, but the influence of year of birth and calving were found to be not significant in the model.

3.3 Results and discussion

Production parameters of the H and FxH cows are presented in Table 3.1 while differences across lactations are presented in Table 3.2.

3.3.1 The milk production parameters of Holstein and Holstein X Fleckvieh cows.

The least square means and standard errors of the genotype effect on milk production are depicted in Table 3.1

Table 3.1 Least square means (±s.e.) of 305-day production parameters of Holstein and Fleckvieh x Holstein cows

	Breeds		
Parameters	Holstein	Fleckvieh x Holstein	P
Number of records	117	172	-
Milk (kg)	6330±117	6108±97	0.14
Protein (kg)	202±3.5	200±2.9	0.76
Fat (kg)	252±4.7	251 ±3.9	0.37
Protein (%)	3.20^{a}±0.02	3.30^{b}± 0.02	<0.001
Fat (%)	3.98^{a}±0.03	4.13^{b}±0.02	<0.001
Component value (kg)	2064±37	2055±30	0.84

^{a,b} Means within the same row with different superscripts differ significantly (P<0.05).

Fleckvieh x Holstein cows produced milk of a higher fat percentage and protein percentage (P<0.01) than H cows, but with the crossbred cows only exhibiting a slightly lower mean production, the difference in fat percentage and protein percentage was not large enough to affect the total fat and protein production and therefore, the component value which is based on fat and protein yield also did not differ between the two breeds. These findings are consistent with results reported in literature for Brown Swiss x Holstein cows, Jersey x Holstein cows (VanRaden & Sanders, 2003), Holstein x Jersey (Ahlborn-Breier & Hohenboken, 1991), as well as preliminary results reported on this study (Muller, 2009). However, these results differ from those in the Californian crossbreeding studies (Heins *et al*., 2007), in which Normande x Holstein, Montbéliarde x Holstein and Scandinavian Red x Holstein cows produced less (P<0.01) milk, fat and protein than purebred Holsteins. In contrast, Goni (2014) found that Fleckvieh x Jersey cows produced more (P<0.05) milk, fat and protein than Jersey cows in a pasture-based feeding system. However, production systems could affect the production of cows differently.

3.3.2 The effect of parity on milk parameters of Holstein and Fleckvieh x Holstein cows

While parity affected (P<0.05) production parameters, genotypes within parity number did not differ (P>0.05) as expected from Table 3.1. However, while milk, fat and protein production did not differ (P>0.05), fat and protein percentages differed (P<0.05) between genotypes. In Table 3.2 these significant differences across parities and within the specific genotype are demonstrated in the columns.

The milk production for both the Holstein and the Fleckvieh x Holstein cows differed (P<0.05) between the first and the second lactation, with no differences (P>0.05) between lactation two and three. In both genotypes the production in the fourth lactation differed (P<0.05) from all three previous lactations. The increase in the milk production from lactation one to two was the largest in the Holsteins, and both genotypes showed an increase of more than 1000 kg of milk from lactation one to two. The decrease in production in lactation four was smaller for the F x H cows, but this difference was also not significant (P>0.05).

This trend was followed by the total fat and total protein production, although fat percentage did not differ (P>0.05) across lactations. Protein percentage decreased significantly from lactation one to lactation two for both the breeds, although not differing (P>0.05) between lactation two and three. The protein percentage differ (P<0.05) between all three previous lactations, with the notable difference of the fourth lactation of the FxH cows that did not differ significantly from all the previous lactations, while the H cows protein percentage did.

The component value differed significantly (P<0.05) from lactation one to two, being markedly higher in lactation two. As the component value is a factor of the total milk, fat and protein production, this was expected.

Heins *et al*. (2007) also reported that milk production of Holsteins increased from lactation one to two and that the increase in production was higher in Holsteins in comparison to the Normande x Holstein, Montbeliarde x Holstein and the Scandinavian Red x Holstein cows, the differences (P<0.01) in milk production being from 9 to 12% in the Normande x Holstein, 5 to 7 % in the Montbeliarde X Holstein and 3 to 6% in the Scandinavian Red x Holstein, when compared to Holsteins.

Table 3.2 Least square means (±s.e.) depicting the effect of parity on the 305-day milk production parameters of Holstein and Fleckvieh x Holstein cows

		Parity number				
Parameters	Breed	1	2	3	4	P
Number of	H	54	33	29	20	-
records	F X H	53	35	24	17	-
Milk (kg)	H	5628^{b} ± 170	6870^{a} ± 198	6764^{a} ± 189	6290^{a,b} ± 280	<0.01
	F X H	5452^{b} ± 148	6547^{a} ± 224	6519^{a} ± 229	6140^{a,b} ± 272	<0.01
Fat (kg)	H	222^{b} ± 6.60	275^{a} ± 8.08	270^{a} ± 7.00	242^{a,b} ± 10.17	<0.01
	F X H	229^{b} ± 5.80	273^{a} ± 9.04	273^{a} ± 10.2	253^{a,b} ± 10.5	<0.01
Protein (kg)	H	183^{b} ± 5.31	218^{a} ± 5.70	211^{a} ± 5.75	192^{a,b} ± 7.00	<0.01
	F X H	186^{b} ± 4.85	215^{a} ± 6.00	214^{a} ± 7.30	202^{a,b} ± 8.48	<0.01
Fat (%)	H	3.96** ± 0.04	4.01* ± 0.05	3.99* ±0.06	3.86* ± 0.07	<0.33
	F X H	4.22** ± 0.04	4.19* ± 0.05	4.20* ± 0.08	4.14* ± 0.07	<0.83
Protein (%)	H	3.27^{a}** ± 0.03	3.19^{a,b}** ± 0.03	3.12^{b}** ± 0.03	3.07^{b}** ± 0.06	<0.01
	F X H	3.43^{a}** ±0.02	3.29^{b}** ±0.03	3.29^{b}** ± 0.06	3.30^{a,b}** ± 0.05	<0.01
Component	H	1859^{b} ± 53.8	2243^{a} ± 60.5	2180^{a} ± 60.3	1974^{a,b} ± 81.5	<0.01
value	F X H	1898^{b} ± 48.7	2214^{a} ± 71.6	2206^{a} ± 77.5	2073^{a,b} ± 86.1	<0.01

^{a,b,c}Means within the same row with different superscripts differ significantly at P<0.05.

*Means of different traits within lactation number differed at (P<0.05); **Means of different genotypes are significantly different (P<0.01)

Component Value = ((6 x fat production) + (13 x protein production))/2

The milk production and milk production parameters across lactations up to lactation 4 shows a large increase in total milk, fat and protein from lactation 1 to 2 (P<0.05) for both genotypes, followed by a gradual decline to lactation 4.

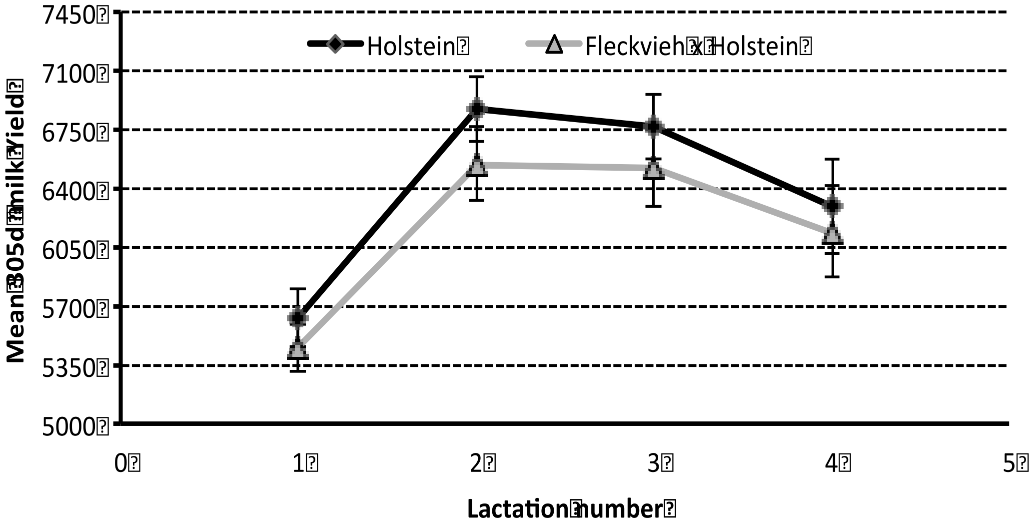

Figure 3.1. Mean milk yield (kg) as affected by genotype and lactation number. Vertical bars around the observed means signify standard errors

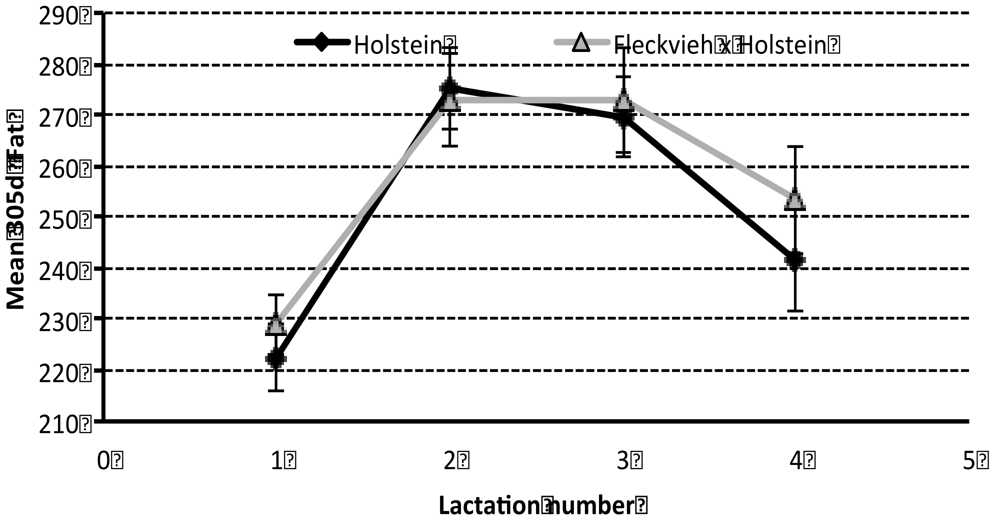

Figure 3.2. Mean fat yield (kg) as affected by genotype and lactation number. Vertical bars around the observed means signify standard errors

The mean fat production of the H vs. FxH cows did not differ (P>0.05) from lactation one to three, with the fat production for both genotypes being higher (P<0.05) from lactation one to two. The two genotypes did not differ significantly (P>0.05). In the California study Heins *et al*. (2007) reported that the Normande x Holstein, Montbéliarde x Holstein and the Scandinavian Red x Holstein had a higher increase in fat production than the Holstein cows from lactation 3 and 4, in contrast to the lower increase when compared to the Holstein in the first to second lactation. However, these differences were not statistically verified. In an earlier report (Heins *et al*., 2006) the fat production of the Scandinavian Red x Holstein cows did not differ (P>0.05) from that of Holstein cows.

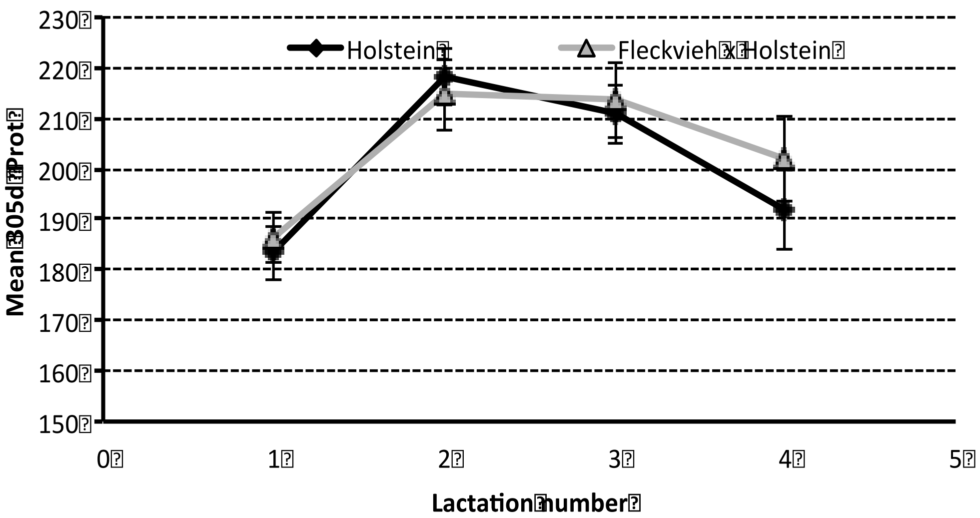

Figure 3.3. Mean protein yield (kg) as affected by genotype and lactation number. Vertical bars around the observed means signify standard errors

The mean protein production increased from lactation one to lactation two, but the difference between the genotypes was non-significant (P>0.05). Similarly, Heins *et al*. (2007) showed that the mean protein production of Normande x Holstein and the Scandinavian Red x Holstein differed at P<0.01, but the Montbéliarde x Holstein only differed to a significance level of P<0.05 when compared to the Holstein.

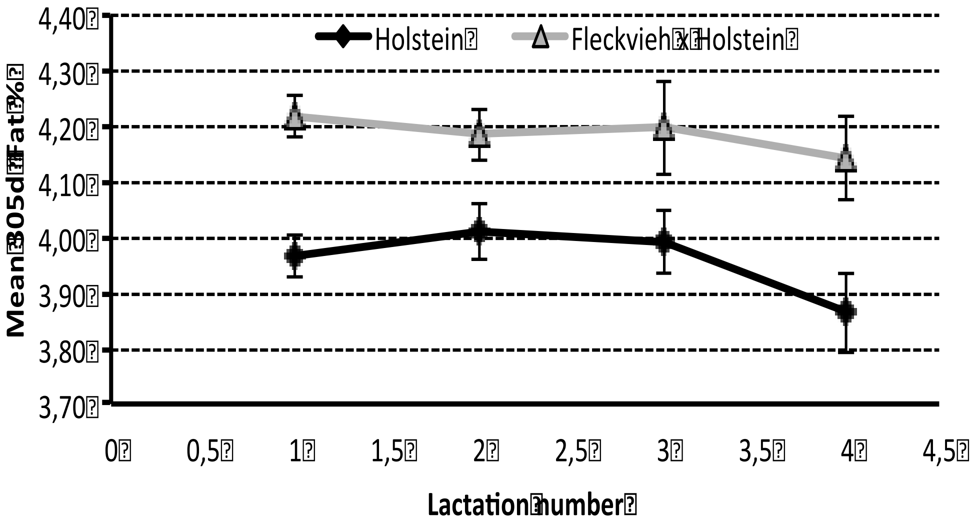

Figure 3.4. Fat percentage as affected by genotype and lactation number. Vertical bars around the observed means signify standard errors

Fleckvieh x Holstein cows had consistently higher fat percentages than H cows for all lactations (P<0.05). This concurred with the results from Heins *et al*. (2006), with the Normande x Holstein, Montbéliarde x Holstein and Scandinavian Red x Holstein cows all having higher fat percentages than purebred H cows (P<0.05).

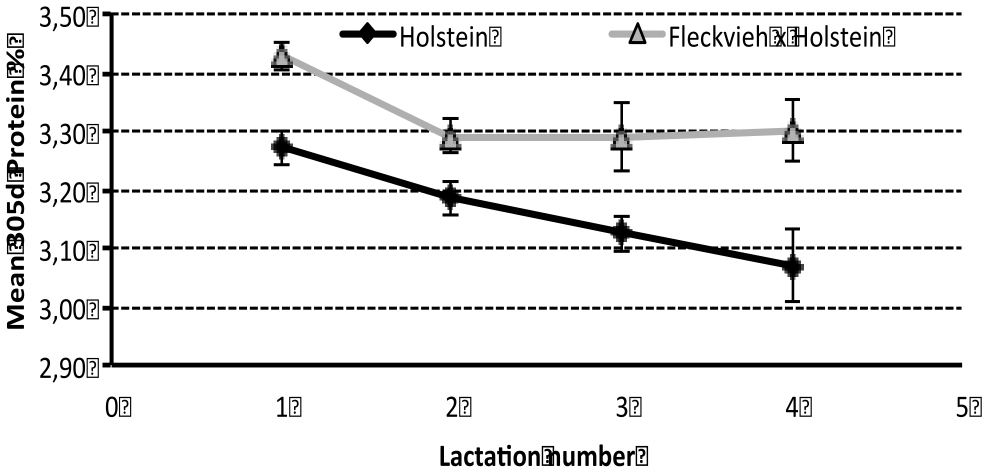

Figure 3.5. Protein percentage as affected by genotype and lactation number. Vertical bars around the observed means signify standard errors

Fleckvieh x Holstein cows had consistently higher protein percentages than H cows for all lactations (P<0.05).

As for milk production, the pattern for Component Value for both breeds was a large increase from lactation one to two, after which the production stayed relatively constant for lactation two and three, and dropped slightly in lactation four.

Mostert *et al*. (2001) found differences in the milk production parameters of cows depending on their calving month. Cows that calved down in autumn and winter tended to have a higher milk production than cows that calved during the warmer months of the year.

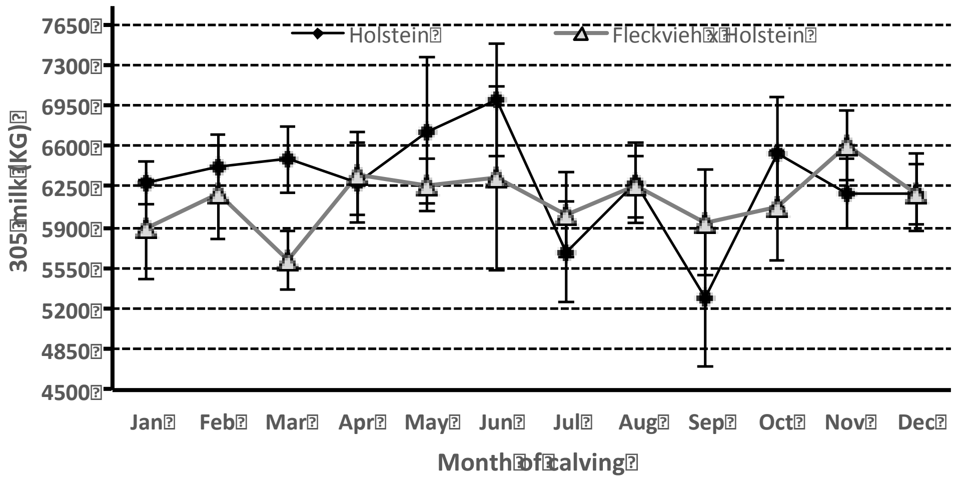

Figure 3.6. Mean Milk yield (kg) as affected by genotype and month of calving. Vertical bars around the observed means signify standard errors

Though it seems from Figure 3.6 that there was an increase in the milk production for the Holstein cows that calved down during May and June, this difference was, however, not significant. None of the differences between the milk production totals for H vs. FxH cows for the different calf months showed any significant differences (P>0.05).

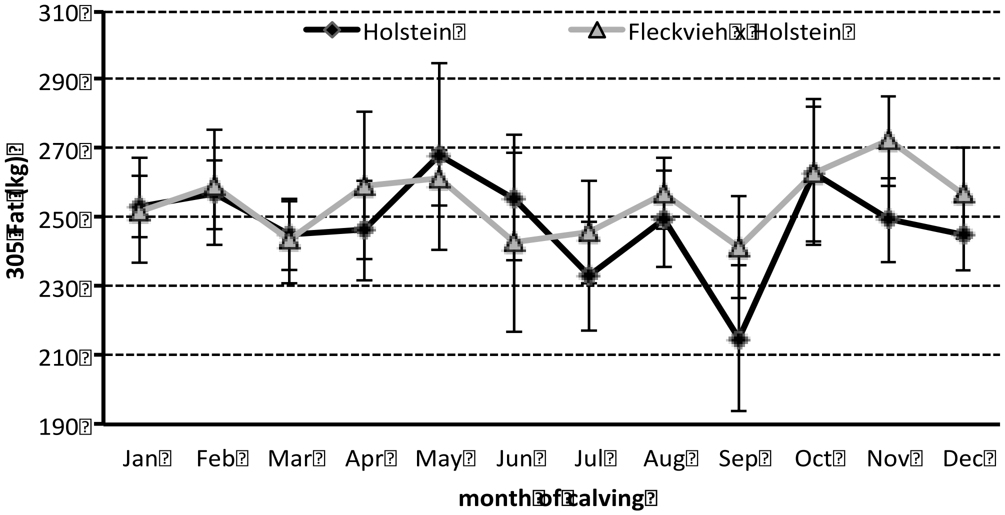

Figure 3.7. Mean fat yield (kg) as affected by genotype per month of calving. Vertical bars around the observed means signify standard errors

The total fat production did not differ (P>0.05) between H and FxH cows for any of the calving months.

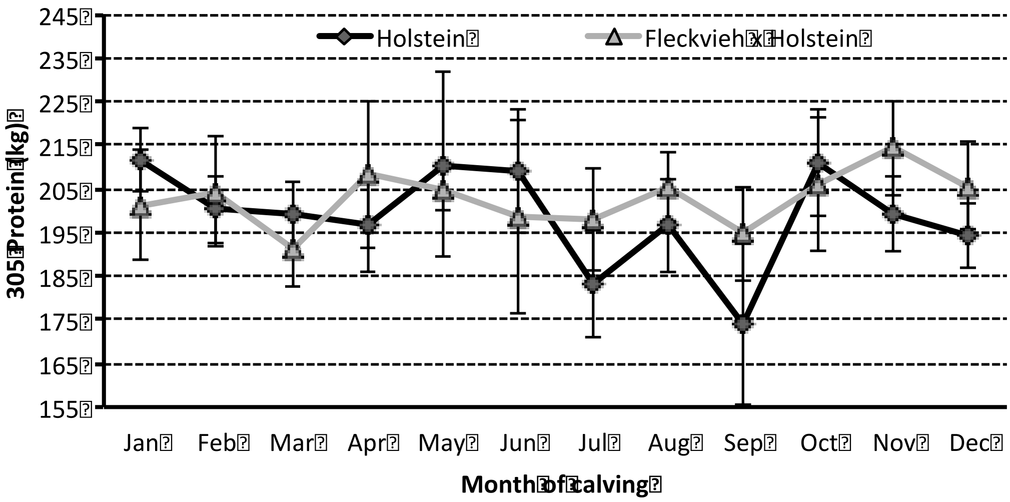

Figure 3.8. Mean protein yield (kg) as affected by genotype per month of calving. Vertical bars around the observed means signify standard errors

The protein production did not differ (P>0.05) between H and FxH cows, for any of the calving months.

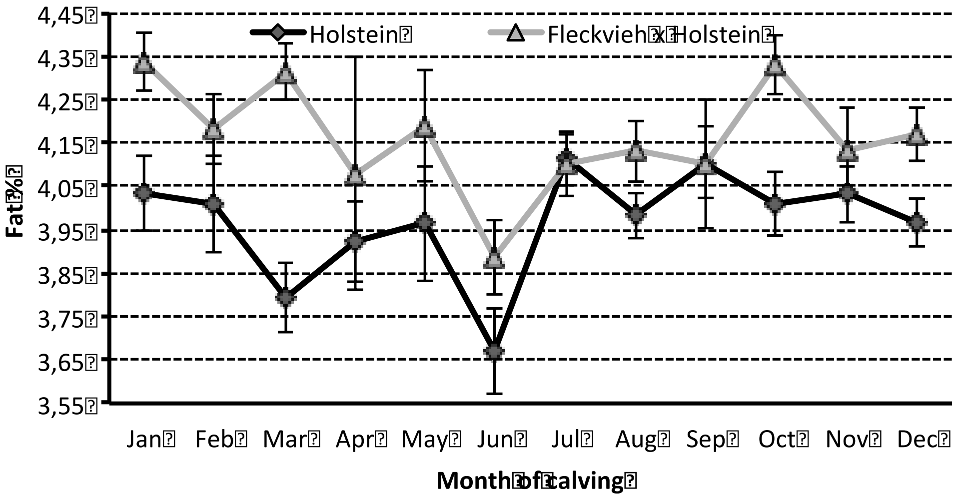

Figure 3.9. Fat percentage as affected by genotype and month of calving. Vertical bars around the observed means signify standard errors

The fat percentage of the H and FxH cows did differ for the interaction of calving month and genotype (P<0.05). Specifically the difference was significant for Jan (P<0.05), March (P>0.05) and October (P<0.05).

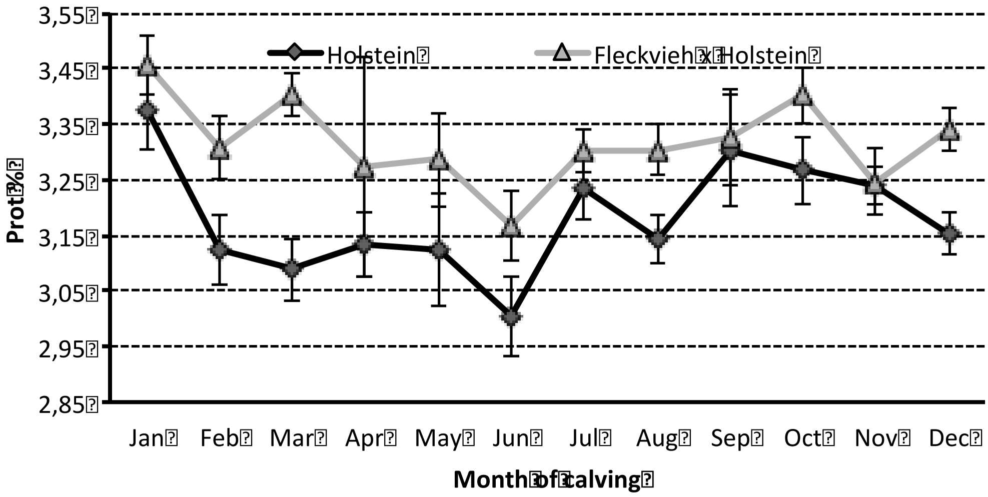

Figure 3.10. Protein percentage as affected by genotype and month of calving. Vertical bars around the observed means signify standard errors

The protein percentage in the milk of Holstein cows was lower (P<0.05) than that of Fleckvieh x Holstein cows for Calving month and for genotype, but showed no significant interaction between genotype and calving month (P>0.05). There only significant protein% differences for H vs. FxH were in March (P<0.001)

3.4 Conclusion

The milk, fat and protein production of H and FxH cows did not differ (P>0.05) while the fat and protein percentage of milk differed (P<0.05) being higher in FxH cows. All production parameters increased from first to second lactation after which production declined to fourth lactation although at higher production levels than first lactation cows.

3.5 References

Ahlborn-Breier, G. & Hohenboken, W.D., 1991. Additive and non-additive genetic effects on milk production in dairy cattle: evidence of major individual heterosis. J. Dairy Sci. 74: 592 – 602.

Caraviello, D.Z., 2004. Crossbreeding dairy cattle: Dairy updates. Reprod Genet. 610: 1 – 6.

Carey, V.A., Saayman, D., Archer, E., Barbeau, G. & Wallace, M., 2008. Viticulture terroirs in Stellenbosch, South Africa. I. The identification of natural terroir units. J. Int. Sci. Vigne Vin. 42: 169 – 183.

Dechow, C.D., Rogers, G.W., Cooper, J.B., Phelps, M.I. & Mosholder, A.L., 2007. Milk, fat, protein, somatic cell score, and days open among Holstein, Brown Swiss and their crosses. J. Dairy Sci. 90: 3542 – 3549.

Goni, S., 2014. Production and reproduction performance of Jersey and Fleckvieh x Jersey cows in a pasture-based system. MSc(Agric) Thesis, University of Stellenbosch, Stellenbosch, South Africa.

Heins, B.J., Hansen, L.B. & Seykora, A.J., 2006. Production of pure Holsteins versus crossbreds of Holstein with Normande, Montbéliarde and Scandinavian Red. J. Dairy Sci. 89: 2799 – 2804.

Heins, B.J., Hansen, L.B. & Seykora, A.J., 2007. The California experience of mating Holstein cows to A.I. sires from the Swedish Red, Norwegian Red, Montbéliarde, and Normande breeds. University of Minnesota Report on research. pp. 1 - 18

Lievaart, J.J., Noordhuizen, J.P.T.M., van Beck, E. van der Beek, C., van Risp, A. Schenkel, J. & van Veersen, J., 2005. The hazard analysis critical control point's (HACCP) concept as applied to some chemical, physical and microbiological contaminants of milk on dairy farms. A prototype. Veterinary Quarterly 27(1): 21 – 29.

Mackle, T.R., Bryant, A.M., Petch, S.F., Hill, J.P. & Auldist, M.J., 1999. Nutritional influences on the composition of milk from cows of different protein phenotypes in New Zealand. J. Dairy Sci. 82: 172 – 180.

Mostert, B.E., Theron, H.E. & Kanfer, F.H.J., 2003. Derivation of standard lactation curves for South African dairy cows. SA J. Anim. Sci. 33: 70 – 77.

Mostert, B.E., Theron, H.E. & Kanfer, F.H.J., 2001. The effect of calving season and age of calving on production traits of South African dairy cattle. SA J. Anim. Sci. 31: 205 – 214.

Muller, C.J.C. & Botha, J.A., 2008. Preliminary results on crossbreeding Jerseys with Fleckvieh sires. Els. J. 1: 2 – 3.

Muller, C.J.C., Botha, J.A., Cloete, S.W.P. & Potgieter, J.P., 2009. Preliminary results on the comparative performance of primiparous Holstein and Fleckvieh x Holstein Dairy cows. Proc. Assoc. Advmt. Anim. Breed. Genet. 18: 616 – 619.

Oosthuizen, P.A., Dugmore, T.J., Du Toit, F.J. & van Zyl, E.A., 2015. Dairying in Sub-Tropical regions – Makhathini Research Station. Poster presentation. 48th SASAS Congress. 21-23 September 2015. Pp. 85.

Palmquist, D.L. & Beaulieu, A.D., 1993. ADSA foundation symposium: milk fat synthesis and modification. Feed and animal factors affecting milk fat composition. J. Dairy Sci. 76: 1753 – 1771.

Statistical Analysis systems, 2009. SAS User's guide. SAS Institute Inc., Cary, N.C. USA.

VanRaden, P.M., & Sanders, A.H., 2003. Economic merit of crossbred and purebred US dairy cattle. J. Dairy Sci. 86: 1036 – 1044.

CHAPTER 4

The reproductive performance of Holstein and Fleckvieh x Holstein cows and heifers

Abstract

Reproduction performance in a dairy herd is of great importance, as each new lactation period is initiated by cows calving down. Female progeny born from this is also the next generation of cows in a dairy herd replacing cows that are being culled from a dairy herd. Various studies have indicated that the Holstein breed is experiencing fertility problems as observed in more days open, fewer cows conceiving soon after calving and fewer cows calving multiple times. The decrease in fertility in the Holstein breed has also been experienced in South Africa as the calving interval of cows in milk recording has increased over time. In this study the fertility of Holstein (H) and Fleckvieh x Holstein (FxH) heifers and cows in a total mixed ration feeding system was compared. Insemination dates, pregnancy check results and calving dates were used to estimate fertility parameters for heifers and cows. Fertility parameters for H vs. FxH heifers did not differ (P>0.05), i.e. age at first insemination was 15.4±0.30 vs. 15.5±0.33 months, age at conception 17.2±0.35 vs. 17.3±0.34 months and age at first calving 26.4±0.37 vs. 26.5±0.24 months of age, respectively. Fertility parameters of H vs. FxH cows differed (P<0.05), i.e. the interval from calving to first service being shorter for FxH cows at 86.2±5.3 days and 104.7±5.0 days for H cows. However, days open and services to conception did not differ significantly, being 153.1±6.8 and 135.3±7.1 for days open and 2.24±0.14 and 2.30±0.15 for the H vs. FxH cows, respectively. These traits were strongly affected by the standard of reproduction management with regards to inseminator efficiency. The proportion of cows conceiving within 100 days post partum differed (P=0.08) being 37±6 and 48±6%, respectively while the proportion of cows conceiving within 200 days post partum did not differ (P>0.05) being 76±4 and 81±4%, respectively. These results concur with data from other studies using crossbred cows.

4.1 Introduction

A number of studies has shown that selecting for high milk production, has led to a concurrent decrease in fertility (VanRaden *et al*., 2004, Haile-Mariam *et al*., 2013, Clark *et al*., 2007, Hoffman & Funk, 1992). Improvement in the milk production performance of Holstein cows has mostly been driven by genetic improvement (genetic selection has accounted for more than 55% of the phenotypic gains in yield traits), with a concurrent 24 day increase in the interval from calving to conception (Shook, 2006).

The fertility of dairy cows is one of the most important factors that impact on the financial viability of a dairy herd. Reproductive failure causes economic losses due to prolonged calving intervals, increased insemination costs, fewer replacement heifers available, loss of income from the sale of bull calves, and ultimately leading to the culling of dairy cows. In the UK, reproductive failure was reported to be the reason for culling in 44% of the first lactation cows (Esselmont & Kossaibati, 1997).

This is also the case in South Africa, where selection for increased milk yield in the Elsenburg herds resulted in decreased fertility in primiparous Holstein cows (Muller *et al*., 2000). The effect was however small, i.e. 4 days extra for each 1000 kg more milk for days to first insemination and 11 days to conception. Small R^2-

values indicate that other factors in addition to milk yield affected reproduction in this sample of Holstein cows. Makgahlela *et al*. (2007) found an unfavourable genetic association between calving interval and yield traits, and that female fertility should be included in the breeding objective for South African Holstein cattle to stop the decline in *post-partum* cow fertility due to selection based mainly on yield traits.

Makgahlela *et al*. (2008) reported that the calving interval (CI) of South African Holstein cattle has increased from 386 days in 1986 to 412 days in 2004 indicating a decline in the fertility of Holstein cows in milk recording. A longer calving interval indicates that the interval from calving to conception is increasing because cows are not becoming pregnant quickly and reliably after calving. However, it is not clear whether the increase in CI is related to a change in the genetic merit for fertility in Holsteins or whether changes in the management style of dairy farming has resulted in this poorer performance.

Dairy producers worldwide have tried to overcome this problem, sometimes by using crossbreeding (Clark *et al*., 2007). The results of a producer survey regarding crossbreeding on US dairy farms reported by Weigel & Barlass (2003) indicated that the perception amongst dairy farmers was that by using crossbreeding, improvements in fertility, calving ease, longevity and component percentages were observed. The most popular breeds for crossbreeding amongst these producers was Jersey and Brown Swiss bulls mated to Holstein cows. Respondents indicated that Jersey and Brown Swiss crossbred Holsteins had a clear advantage in longevity relative to purebred Holsteins, and conception rates were similar to the (high) conception rates typically achieved in purebred Jersey mating. Respondents also indicated that milk composition was improved in crossbred cattle, but producers cited some difficulties in marketing crossbred breeding stock and bull calves, and noted that the lack of uniformity within the milking herd created management challenges.

Heins *et al*. (2006) established that the number of days from calving to first insemination was less ($P<0.05$) in Normande x Holstein and Montbéliarde x Holstein cows in comparison to Holstein cows being 62 and 65 days compared to 69 days for purebred Holsteins, respectively. They also found that the first service conception rate of the Normande x Holstein and Montbéliarde x Holstein was higher ($P<0.05$) at 35% and 31% respectively, compared to 22% for purebred Holsteins. All three crosses (Normande x Holstein, Montbéliarde x Holstein, Scandinavian Red x Holstein) had fewer days open ($P<0.01$) than purebred Holsteins (least square means for purebred Holsteins, Normande x Holstein, Montbéliarde x Holstein and Scandinavian Red x Holstein were 150±4.1, 123±3.8, 131±4.4 and 129±4.6 days respectively). Animals that calved down for the first time at 23 to 25 months were more fertile, had better milk production and lived longer ($P<0.001$) (Cooke *et al*., 2013).

Blöttner *et al*. (2011) found that Brown Swiss x Holstein cows had fewer days to first breeding ($P<0.01$) than purebred Holstein cows during second lactation, and although not significantly, crossbred cows also showed a tendency of fewer days to first breeding during third lactation.

Goni (2014) compared the fertility traits of the Jersey and Fleckvieh x Jersey cows showing that crossbred cows had a higher pregnancy percentage ($P<0.05$), fewer days from calving to first service ($P<0.05$) and more ($P<0.05$) cows were inseminated before 80 days in milk. There were, however, no significant difference in days open (DO) or number of services per conception. In contrast, no significant differences were found in the fertility traits of Fleckvieh x Jersey heifers in comparison to purebred Jersey heifers.

The aim of the present study was to compare the fertility of FxH heifers and cows to that of purebred H heifers and cows.

4.2 Materials and methods

4.2.1 Site description:

The trial was conducted at the Elsenburg Research Farm, approximately 16 km from Stellenbosch in the Western Cape Province of South Africa. The farm is located at 33° 50' 33" S and 18° 49' 49" N. The area is characterised by a Mediterranean type climate with cool wet winters and warm dry summers. The long term average rainfall for the Stellenbosch area at different sites varies between about 550 and 960 mm/year (Carey *et* al., 2008). Most rainfall occurs mainly during the winter from May to September. .

4.2.2 Experimental animals

The study was started with 24 Holstein and 24 Fleckvieh x Holstein heifers. Heifers were bought from a commercial dairy farm. Heifers included in the study were usually the youngest ones at the collection date. The goal was to obtain calves that were within five days from birth. This ensured that the selection was random. The female progeny of these heifers were also later on included in the trial to increase the number of experimental animals. Cows were also maintained in the herd for as long as possible to increase the number of lactation records. Culling of cows was based on standard herd management reasons, i.e. not becoming pregnant or getting mastitis.

Colostrum was fed to the calves until 5 days of age. The calves was transported to Elsenburg and put into individual pens. On arrival they received pre-heated colostrum collected from cows that had calved in the Elsenburg herd. The calves would then receive colostrum for another five days and thereafter full cream milk at 5% of body weight (or approximately 2 litres of milk at each feeding) twice a day until weaning at 6 weeks of age.

A calf starter meal containing 18% CP was provided *ad libitum* from seven days of age until two months of age. After this period, a growth meal containing 15% CP was provided *ad libitum* until six months of age. From six months of age a growth meal containing 13% CP was provided until the calves were approximately 12 months old. At about 13 months of age heifers were put in service group where they were observed for heat detection. After being confirmed pregnant heifers were put with the dry cows on kikuyu pasture until about three weeks before their expected calving dates. They were then put with the steam-up being fed a pre-calving steam-up concentrate.

All heifers were inseminated at approximately 13 months of age, and if not confirmed pregnant by 15 months of age, they were synchronised to facilitate insemination.

Cows were observed for heat detection and inseminated as soon as heat was detected after calving. Holstein cows and heifers were inseminated with Holstein semen and Fleckvieh x Holstein cows and heifers were inseminated with Fleckvieh semen. Cows not confirmed pregnant after 150 days was synchronised for insemination.

4.2.3 Data collection

Using birth dates, insemination dates and pregnancy check results, a number of fertility parameters for heifers were estimated, i.e. age of heifers at first insemination, age at conception and age at first calving. Binary traits, i.e. whether heifers were inseminated before 15 and 18 months of age, were recorded. For cows fertility parameters were based on calving dates, insemination dates and pregnancy check results from which interval traits such as the number of days from calving to first insemination and number of days from calving to conception (days open) were estimated. For both the heifers and the cows, the number of inseminations per conception was recorded. Binary traits, i.e. whether cows became pregnant within 100 and 200 days after calving, were also recorded.

4.2.4 Statistical analysis

The data were analysed using PROC GLM procedures from SAS (2009). The effects of genotype on age at first AI, conception age, services per conception and age at first calving were analysed using ANOVA for the heifers, and the effects of genotype on calving to first service, days open, services per conception and number of lactations were analysed using ANOVA for the cows. Repeated records were considered as uncorrelated to meet the assumptions for ANOVA. Least square means were calculated for each effect, where they separated using PDIFF STDERR of SAS (2009).

The model used was $Y_{ij} = \mu + B_i + P_j + e_{ij}$

where:

(1) Heifers:

Y_i = Age at first AI, conception age, services per conception and age at first calving

μ = population mean

B_i = fixed effect of genotype (I = Holsteins, Fleckvieh x Holsteins)

e_i = random error

(2) Cows:

Y_{ij} = interval calving to first AI (days), interval calving to conception (days), the number of services per conception, percentage of cows inseminated within 80 days postpartum and the percentages of cows confirmed pregnant within 100 and 200 days in milk, and age at first calving

μ = population mean

B_i = fixed effect of genotype (I = Holsteins, Fleckvieh x Holsteins)

P_j = fixed effect of parity (1,2,3,4)

e_{ij}= random error

Preliminary analyses included the effect of year of birth and calving year, but the influence of year of birth and calving were found to be non-significant in the model.

4.3 Results and discussion

4.3.1 Fertility of heifers

Fertility parameters of H and FxH heifers are presented in Table 4.1. Fertility parameters did not differ (P>0.05) between genotypes with age at first service being 15.5±0.3 and 15.5±0.3 months for H and FxH heifers respectively. Conception age and age at first calving for H versus FxH heifers was 17.2±0.35 vs. 17.3±0.34 months and 26.4±0.37 vs. 26.5±0.38 months, respectively.

Table 4.1 Fertility parameters (±s.e.) of Holstein heifers vs. Fleckvieh x Holstein heifers (AI = artificial insemination)

Parameters	Holstein	Fleckvieh x Holstein	P
Number of heifers	58	63	-
Age at first AI (months)	15.4 ± 0.3	15.5 ± 0.33	0.85
Conception Age (months)	17.2 ± 0.35	17.3 ± 0.34	0.72
Age at first Calving (months)	26.4 ±0.37	26.5 ±0.38	0.85
Services per conception	2.40 ± 0.24	2.36 ± 0.24	0.89
Proportion of first AI before 15 months of age	0.62 ± 0.06	0.57 ± 0.06	0.59
Proportion of first AI before 18 months of age	0.91 ± 0.04	0.87 ± 0.04	0.47

Lin *et al*. (1984) found year of birth to be highly significant (P<0.01) for days from first service to conception, age at first heat, age at first conception and age at first freshening, conception rate at first service and gestation length. The analysis was done with purebred Holsteins of Canadian and USA origin, Ayrshires of Canadian and Finnish origin, Brown Swiss cows USA origin, Norwegian Red cattle, and their crossbreeds.

4.3.2 Fertility of lactating cows

Table 4.2 Fertility parameters (± s.e.) of purebred Holstein cows vs. Fleckvieh x Holstein cows

Parameters	Holstein	Fleckvieh x Holstein	p
Number of lactation records	158	142	-
Average lactation number	2.5 ± 0.1	2.4 ± 0.1	0.58
Interval calving to first service (days)	104.7[a] ± 5.0	86.2[b] ± 5.3	<0.01
Proportion of cows inseminated <80 days after calving	0.45 ± 0.04	0.50 ± 0.04	0.32
Interval calving to conception (days)	153.1* ± 6.8	135.3* ±7.1	0.07
Services per conception	2.24 ± 0.14	2.30 ± 0.15	0.81
Calving interval (days)	422 ± 6	410 ± 6	0.17
Proportion of cows pregnant <100 days after calving (%)	37* ± 6	48* ± 6	0.08
Proportion of cows pregnant < 200 days after calving (%)	76 ± 4	81 ± 4	0.31
Proportion of heifers pregnant after first insemination (%)	33 ± 4	32 ± 4	0.92
Pregnant after 2 inseminations (%)	54 ± 4	56 ± 4	0.74
Pregnant after 3 inseminations (%)	63 ± 0.03	69 ± 0.04	0.30
Final pregnancy rate (4 or more inseminations) (%)	78 ± 0.03	82 ± 0.04	0.41

[a,b]Values in the same row with different superscripts differ at P <0.05; *Values in the same row differ at P=0.07.

The FxH cows had fewer (P<0.01) days from calving to first service than H cows, being 86.2±5.3 and 104.7±5.04 days, respectively. This indicated that crossbred cows cycled earlier and showed oestrus more readily. This agrees with data from Williams (2007) who found that Holstein x Jersey cows cycled earlier postpartum (P<0.05) than purebred Holstein cows. Holstein cows' first service conception rates were also lower than that of the Holstein x Jersey cows, and fewer Holstein cows were diagnosed as pregnant at 90 days post calving, although these differences were not statistically significant (Williams, 2007).

The interval from calving to conception (days open) tended (P=0.07) to be lower for FxH cows in comparison to that of H cows, i.e. 135.3±7.1 vs. 153.1±6.8 days respectively. Heins *et al.* (2007) found that days open were less (P<0.05) for Normande x Holstein, Montbeliade x Holstein and for Scandinavian Red x Holstein in comparison to Holsteins, being 122, 124, 131 and 147 days, respectively generally concurring with the present study.

There was a tendency (P=0.08) for a greater proportion of FxH cows to be pregnant by 100 days post partum in comparison to H cows, being 0.48±0.06 vs. 0.37±0.06. Although the proportion of FxH cows confirmed pregnant by 200 days post partum was higher in absolute terms in comparison to H cows, the difference was not significant (P>0.05). Clark *et al*. (2007) indicated that Holstein-Friesian x Jersey cows had improved pregnancy rates in numerous study's, which was corroborated in this study, though the results were non-significant (P>0.10) for pregnancy rate for all insemination numbers.

Vesely *et al*. (1986) found that the survival of calves from a H-line (progeny from Holstein cows inseminated with US and Canadian Holstein semen) x A-line (progeny from Ayrshire cows inseminated with Finnish Ayrshire, US Brown Swiss and Norwegian Red bulls) cows was higher (P<0.05) when compared to Holsteins. Lin *et al*. (1984) also reported a lower (P<0.05) disposal rate of crossbred heifers from birth to breeding age. The study, however, did not find an improvement (P>0.05) in conception rate or longevity of the crossbred cows versus the purebred Holsteins, Ayrshires, Brown Swiss or Norwegian Red cows.

4.4 Conclusion

The fertility of FxH heifers did not differ from that of H heifers for age of first AI, conception age or age at first calving. When the fertility of the FxH cows were compared to that of H cows, a significant difference for calving to first service in favour of the crossbred cows was demonstrated. The FxH cows tended to have fewer days open and a shorter calving interval period when compared to H cows, although the days open and calving interval did not differ significantly, This trend was corroborated by the higher percentage of cows pregnant at within 100 days and 200 days after calving as well as in the final pregnancy rate of 83% for the FxH cows versus 80% for the Holstein cows.

4.5 References

Blöttner, S., Heins, B. J., Wensch-Dorendorf, M., Hansen, L.B. & Swalve, H.H., 2011. Brown Swiss x Holstein crossbreds compared with pure Holsteins for calving traits, body weight, backfat thickness, fertility and body measurements. J. Dairy Sci. 94: 1058 – 1068.

Carey, V.A., Saayman, D., Archer, E., Barbeau, G. & Wallace, M., 2008. Viticulture terroirs in Stellenbosch, South Africa. I. The identification of natural terroir units. J. Int. Sci. Vigne Vin. 42: 169 – 183.

Clark, D.A., Caradus, J.R. Monaghan, R.M., Sharp, P. & Thorrold, B.S., 2007. Issues and options for future dairy farming in New Zealand. New Zealand J. Agric. Res. 50:2, 203 – 221.

Cooke, J.S., Cheng, Z., Bourne, N.E. & Claire Wathes, D. 2013. Association between growth rates, age at first calving and subsequent fertility, milk production and survival in Holstein-Friesian heifers. Open Journal of Animal Sciences. 3(1): 1 – 12.

Esselmont, R.J. & Kossaibati, M.A., 1997. Culling in 50 dairy herds in England. Vet. Rec. 140: 36 – 39.

Goni, S., 2014. Production and reproduction performance of Jersey and Fleckvieh x Jersey cows in a pasture-based system. MSc(Agric) Thesis, University of Stellenbosch, Stellenbosch, South Africa.

Haile-Mariam, M., Bowman P.J. & Pryce, J.E., 2013. Genetic analyses of fertility and predictor traits in Holstein herds with low and high mean calving intervals and in Jersey herds. J. Dairy Sci. 96: 655 – 667.

Heins, B.J., Hansen, L.B. & Seykora, A.J., 2006. Fertility and survival of pure Holsteins versus crossbreds with Holstein and Normande, Montbeliarde and Scandinavian Red. J. Dairy Sci. 89: 4944 – 4951.

Heins, B.J., Hansen, L.B. & Seykora, A.J., 2007. The California experience of mating Holstein cows to A.I. sires from the Swedish Red, Norwegian Red, Montbeliarde, and Normande breeds. University of Minnesota report on research. pp. 1 - 18

Hoffman, P.C. & Funk, D.A., 1992. Applied dynamics of dairy replacement growth and management. J. Dairy Sci. 75: 2504 – 2516.

Lin, C.Y., McAllister, A.J., Batra, T.R., Lee, A.J. Roy, G.L., Vesely, J.A., Wauthy, J.M. & Winter, K.A. 1984. Reproductive performance of crossline and pureline dairy heifers. J. Dairy Sci. 76: 2420 – 2428.

Makgahlela, M.L., Banga, C.B., Norris, D., Dzama, K. & Ng'ambi. J.W., 2007. Genetic correlations between female fertility and production traits in South African Holstein cattle. SA J. Anim. Sci. 37(3): 180 – 188.

Makgahlela, M.L., Banga, C.B., Norris, D., Dzama, K. & Ng'ambi. J.W., 2008. Genetic analysis of age at first calving and calving interval in South African Holstein cattle. Asian J. Anim.Vet. Adv. 3: 197 – 205.

Muller, C.J.C., du Toit, F.J., Singhapol, C. & Botha, J.A., 2000. The effect of milk yield on some reproductive parameters of the Elsenburg Holstein and Jersey herd. SA J. Anim. Sci. 30(1): 34 – 35.

Shook, G.E., 2006. Major advances in determining appropriate selection goals. J. Dairy Sci. 89: 1349 – 1361.

VanRaden, P.M., Sanders, A.H., Tooker, M.E., Miller R.H., Norman, H.D., Kuhn, M.T. & Wiggans, G.R., 2004. Development of a national genetic evaluation for cow fertility. J. Dairy Sci. 87 :2285 – 2292.

Vesely, J.A., McAllister, A.J., Lee, A.J., Batra, T.R., Lin, C.Y., Roy, G.L., Wauthy, J.M. & Winter, K.A., 1986. Reproductive performance of crossbred and purebred dairy cows. J. Dairy Sci. 69: 518 – 526.

Weigel, K.A. & Barlass, K.A., 2003. Results of a producer survey regarding crossbreeding on US Dairy farms. J. Dairy Sci. 86: 4148 – 4154.

Williams, C.M., 2007. Effects of crossbreeding on puberty, postpartum cyclicity and fertility in Pasture-based dairy cattle. MSc thesis. North Carolina State University. Raleigh, North Carolina.

CHAPTER 5

The beef production of Holstein and Fleckvieh x Holstein steers and veal calves in a pasture-based and intensive feeding system

Abstract

To raise or sell bull calves born in a dairy herd is a management decision for all dairy farmers. The income from bull calf sales is usually small in comparison to milk sales; however, with small profit margins in the dairy Industry, this contribution may be significant. Crossbreeding is world-wide being considered as an option to overcome specific problems in dairy herds, notably to improve fertility in dairy cows. Purebred beef breeds can only be used in a terminal crossbreeding programme although this may result in dairy herds not maintaining herd size as beef x dairy cows would not be suitable for milk production. Dual-purpose breeds are therefore more suited for crossbreeding in dairy herds because the milk yield of cows is not affected negatively. In this study bull calves from Holstein (H) and Fleckvieh x Holstein (FxH) cows were raised for slaughter at (i) 18 months of age and (ii) approximately 6 months of age at a carcass weight of about 100 kg for veal. For steers reared to 18 months of age, the mean ± standard error for birth weight (BW), live weight (LW) at *ca.* 18 months of age and average daily gain (ADG) did not differ (P>0.05) between H and FxH steers, being 38.3 ± 1.3 and 41.2±1.3 kg, 450±16 and 468±20 kg and 0.741±0.022 and 0.778±0.023 kg respectively. For veal calves, the BW, LW at marketing and ADG did not differ (P>0.05) between H and FxH, being 39.6±0.70 and 41.4±0.91 kg, 203±1 and 198±2 kg and 0.929±0.020 and 0.953±0.021 kg respectively. As growth curves for steers showed a divergence at 18 months of age, further studies are required to determine the optimal feeding programme to utilize the growth potential of crossbred bull calves as well as marketing age and their effects on beef quality characteristics.

5.1 Introduction

The income potential of beef production from dairy calves is often underestimated on a dairy farm. In the current economic climate, this source of income must be investigated and optimised. Many emerging and small scale farmers consider raising dairy bull calves or steers as a way of getting into farming (Muller, 2014), especially if they are close to a major dairy producing area. To raise or sell bull calves born in a dairy herd is a management decision for all dairy farmers. The income from bull calf sales is usually small in comparison to milk sales, however, with small profit margins in the dairy industry, this contribution to the dairy enterprise may be significant.

Crossbreeding is worldwide being considered as an option to overcome specific problems in dairy herds, notably to improve fertility in dairy cows (Heins *et al*., 2006). Using purebred beef breeds in crossbreeding produces offspring which are not suitable for milk production also limiting the number of replacement heifers in a dairy herd, even if only used on first calving heifers (Osterhoff & Couvaras, 1978), a practice not recommended anymore are heifers are generally the highest genetic merit animals in the herd. Dual-purpose breeds are more suited for crossbreeding in dairy herds to improve beef production as the milk yield of crossbred cows is not affected negatively, with the added advantage of bull calves being more acceptable for the beef market (Muller *et al*., 2013).

In countries with strong dairy industries, beef production from dairy calves accounts for a large proportion of the veal and steers slaughtered. In Ireland, the inclusion of beef production characteristics into the National Dairy herd cattle breeding programme has been accepted due to the increasing pressure to improve efficiency (Grogan *et al*., 2005). This is largely due to the fact that a large proportion of beef have traditionally been produced through crossbreeding in dairy herds (Grogan *et al*., 2005).

Goni (2014) found that the growth rate of Fleckvieh x Jersey veal calves and steers was higher ($P<0.05$) than that of Jerseys veal calves and steers.

The aim of the study was to compare the growth parameters of H and FxH bull calves reared for veal or as beef to 18 months of age.

5.2 Materials and Methods

5.2.1 Site description:

The trial was conducted at the Elsenburg Research Farm, approximately 16 km from Stellenbosch in the Western Cape Province of South Africa. The farm is located at 33° 50' 33" S and 18° 49' 49" N. The area is characterised by a Mediterranean type climate with cool wet winters and warm dry summers. The long term average rainfall for the Stellenbosch area at different sites varies between about 550 and 960 mm/year (Carey *et* al., 2008). Most rainfall occurs mainly during the winter from May to September.

5.2.2 Experimental animals:

The study was conducted at Elsenburg Research Farm approximately 12 km from Stellenbosch. Holstein and FxH bull calves were obtained from a commercial dairy herd within five days from their birth dates. The calves were fed colostrum on their farm of birth, and after being transported to Elsenburg, calves were put into individual pens, and fed pre-heated colostrum for at least another five days. Bull calves were weighed on arrival and divided into four groups, the treatments assigned being genotype (H and FxH), and production system, i.e. (1) reared as veal to a live weight of about 200 kg or a final carcass weight not exceeding 100 kg (at about 6 months of age) and (2) marketing age at 18 months of age. Bull calves being born in the herd from the cows being used in the milk production study were also included into the study. Bull calves from both genotypes with birth dates not differing more than 7 days were included in the beef production study as they had to experience similar feeding and environmental conditions over the 18 month rearing period. .

Calves received full cream milk at 5% of body weight twice a day until weaning at approximately 6 weeks of age. A calf starter meal containing 18% crude protein was provided from day seven of age, *ad libitum*, to stimulate rumen development. This meal was provided up to the age of two months, after which the calves received a growth meal containing 15% crude protein, also provided *ad libitum*, up to the age of approximately six months. Veal calves were slaughtered just before they reached a live weight of 200 kg for a carcass weight of less than 100kg. The 18 month marketing age group was moved to kikuyu pasture from six months of age. They were supplemented with a 15% CP growth meal up to 12 months of age after which they were on rain-fed kikuyu pasture. All steers were marketed as close to 18 months of age as possible.

All bull calves in the beef production system were dehorned and castrated using a Burdizzo at approximately two months of age.

5.2.3 Data collection:

During the study, the birth weights of all the calves were recorded, as well as their monthly live weights up to slaughter. The end and birth weights were used to determine the average daily gain of veal calves and steers. After being slaughtered as steers or veal, the hot and cold carcass weights, as well as the dressing percentage was recorded.

5.2.4 Statistical analysis

The data were analysed using PROC GLM procedures from SAS (2009). The effects of genotype on birth weight (BW), live weight at marketing age, average daily gain (ADG), hot carcass weight, cold carcass weight, dressing percentage and marketing age, were analysed using ANOVA. Repeated records were considered as uncorrelated to meet the assumptions for ANOVA. Least square means were calculated for each factor, where they were separated using PDIFF STDERR of SAS (2009).

The following model was adopted for each of the traits in each of the two genotypes for steer and veal production.

$Y_i = \mu + B_i + e_i$

Where:

Y_i = birth weight, body weight at marketing age, average daily gain, hot and cold carcass weights, dressing percentage and marketing age of the i^{th} veal calf or steer

μ = population mean

B_i = *fixed effect of genotype (I = Holsteins, Fleckvieh x Holsteins)*

e_i = random error

5.3 Results and Discussions

5.3.1 Growth and slaughter quality of Holstein and Fleckvieh X Holstein steers

Table 5.1 Least square means (±s.e.) depicting the effect of genotype on the growth performance of Holstein and Fleckvieh x Holstein steers

Variables	**Holstein**	**Fleckvieh x Holstein**	**P**
Number of records	16	14	-
Birth weight (kg)	38.5±1.3	41.0±1.3	0.20
Live weight at 18 months (kg)	445±16	473±20	0.29
Average daily gain (kg/d)	0.741±0.022	0.778±0.023	0.25
Hot carcass weight (kg)	213*±7	232*±7	0.08
Cold carcass weight (kg)	207*±7	226*± 7	0.08
Dressing (%)	0.479±0.010	0.494±0.010	0.33

*Means within the same row differ at P<0.10

The birth weight of H and FxH bull calves did not differ (P>0.05), being 38.5±1.3 and 41.0±1.3 kg for H and FxH calves respectively. The live weight at 18 months and average daily gain (ADG) were also not found to be statistically different (P>0.05), but the polynomial growth curve and the higher ADG of 0.778±0.023 kg/day of the FxH steers vs. 0.741±0.022 kg /day of the Holstein steers indicated that the crossbred bull calves seems to indicate a faster growth rate from about 10 months of age possibly indicating genotype differences at a larger age.

The hot and cold carcass weights tended (P=0.08) to differ at 213±7 vs. 232±7 kg and 207±7 vs. 226±7 kg for H and FxH steers, respectively. This indicates that more meat could be sold for the F x H steers, which is advantageous for the farmer. The dressing percentage was, however, not different (P>0.05) for the two genotypes.

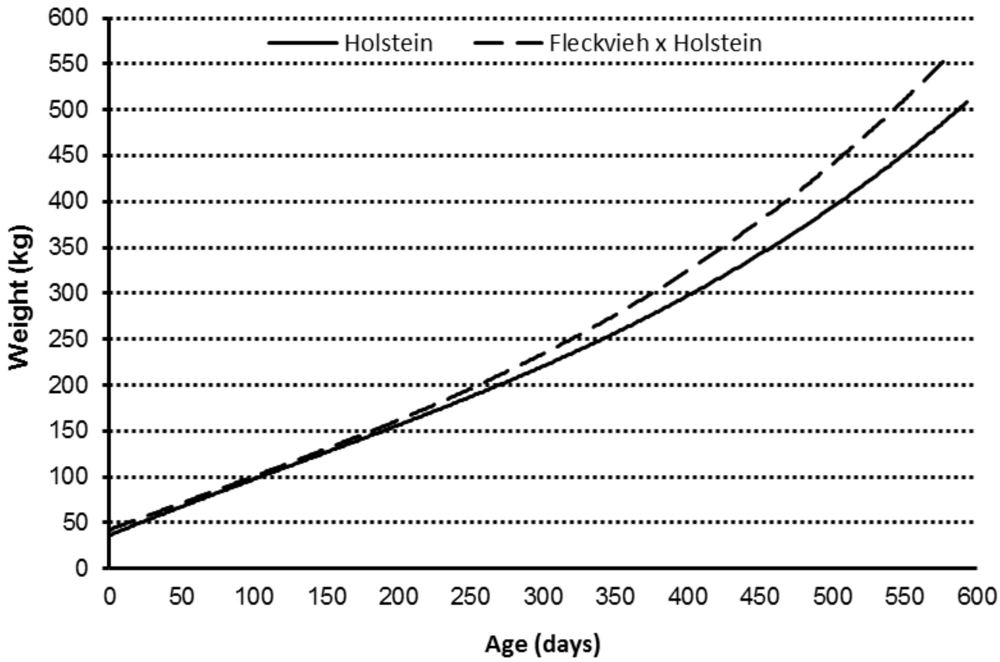

Figure 5.1 The live weight against age in days for Holstein and Fleckvieh x Holstein steers

5.3.2 Growth and slaughter quality of Holstein and Fleckvieh X Holstein veal calves

Table 5.2 Least square means (±s.e.) depicting the effect of genotype on the growth performance of Holstein and Fleckvieh x Holstein veal calves

Variables	Holstein	Fleckvieh x Holstein	P
Number of records	37	34	
Birth weight (kg)	40.0±0.79	41.2±0.81	0.32
Body weight at slaughter	202±1.7	199±1.7	0.16
Average daily gain (kg/d)	0.929±0.020	0.953±0.021	0.40
Hot carcass weight (kg)	101.5±1.2	101.2±1.3	0.86
Cold carcass weight (kg)	98.5±1.4	97.4±1.4	0.58
Dressing (%)	0.502±0.003	0.509±0.004	0.25
Marketing age (m)	5.87±0.17	5.85±0.11	0.95

As with the H and FxH steers, birth weights did not differ (P>0.05) being 40.0±0.79 for H and 41.2±0.81 for FxH calves. The average daily gain (ADG) for H veal calves did not differ (P>0.05) from FxH veal calves (Table 5.2). Holstein and FxH veal calves were marketed at similar live weights, i.e. a carcass weight of approximately 100 kg, therefore genotypes did not differ (P>0.05), and no difference were found in marketing age. All carcass characteristics i.e. hot carcass weight, cold carcass weight and dressing % did not differ (P>0.05)

5.4 Conclusion

There were no significant differences for birth weight, live weight at marketing age or average daily gain for FxH and H bull calves. Further studies are required to determine the optimal feeding programme to utilise the growth potential of crossbred bull calves, marketing age and its effect on beef quality characteristics, as there are indications that there might be scope for improvement of the growth rate of the F x H bull calves. The dressing percentages of H vs. FxH steer and veal calves also did not differ (P>0.05), indicating that the H and FxH bull calves can be profitably raised as veal calves and as steers, depending on the prevailing market conditions.

5.5 References

Carey, V.A., Saayman, D., Archer, E., Barbeau, G. & Wallace, M., 2008. Viticulture terroirs in Stellenbosch, South Africa. I. The identification of natural terroir units. J. Int. Sci. Vigne Vin. 42: 169 – 183.

Goni, S., 2014. Production and reproduction performance of Jersey and Fleckvieh x Jersey cows in a pasture-based system. MSc(Agric) Thesis, University of Stellenbosch, Stellenbosch, South Africa.

Grogan A., Wickham, B., Olori V., & Cromie A., 2005. Strategies for European Fleckvieh cattle breeding to optimize dual-purpose breeding particularly for beef production. Stočarstvo 59(5): 339 – 345.

Heins, B.J., Hansen, L.B. & Seykora, A.J., 2006. Calving difficulty and stillbirths of pure Holsteins versus crossbreds of Holstein with Normande, Montbéliarde and Scandinavian Red. J. Dairy Sci. 89: 2805 – 2810.

Muller, C.J.C. 2014. Beef production from dairy herds. Els. J. 11(4): 57 – 59.

Muller, C.J.C., Goni, S., Dzama, K. & Botha, J.A., 2013. The beef production of a Jersey herd as affected by crossbreeding using Fleckvieh sires. Proc. Assoc. Advmt. Anim. Breed. Genet. 20: 443 – 446.

Osterhoff, D.R. & Couvaras, S., 1978. Is beef production from South African dairy herds possible? J. SA Vet. Assoc. 49(1): 15 – 18.

Chapter 6:

Growth parameters of Holstein and Holstein x Fleckvieh heifers

Abstract

The growth rate of dairy heifers has been shown to affect milk production parameters as well as fertility parameters in dairy cattle. An accelerated heifer growth rate must be applied to enable breeding heifers at an early age without resulting in high fat deposits in the udder causing a negative effect on milk production. This necessitates using breed guidelines to monitor the growth rate of the heifers reared as replacements in a dairy herd. The aim of the study was to compare the live weight and growth rate as well as the body size, i.e. girth circumference and shoulder height of Holstein (H) and Fleckvieh x Holstein (FxH) heifers from birth to first calving. The heifer calves were fed a starter meal containing 18% CP *ad libitum* from seven days of age until two months of age, after which a growth meal containing 15% CP was fed according to general feeding guidelines until six months of age. From six months of age a growth meal containing 14% CP was provided until the calves were approximately 12 months old. At about 13 months of age heifers were put in service group and when confirmed pregnant, heifers were put with the dry cows on kikuyu pasture until about three weeks before their expected calving dates. They were then put with the steam-up cows being fed a pre-calving steam-up concentrate. The results of the trial indicate that the birth weight of H and FxH heifers did not differ significantly, being 37.7±0.65 vs. 37.4±0.71, but that F_1 FxH heifers had a higher average daily gain (ADG determined with a linear regression fitted to obtain individual ADG's) than H heifers, being 0.813±0.021 kg/day and vs. 0.696±0.017 kg/day, respectively. This resulted in absolute heavier live weights at first calving, although not differing significantly. Body size traits, i.e. shoulder height and girth circumference did not differ between H and FxH heifers.

6.1 Introduction

Crossbreeding in the dairy industry is becoming popular in some parts of the world because of heterosis effects on survival traits. The growth rate of Holstein heifers has an effect on the milk production parameters and fertility of dairy cows (Krpálková *et al*., 2014). Hoffman *et al*. (1996) demonstrated that heifers fed diets with increased energy for accelerated growth had a higher average daily gain and calved approximately three months earlier than conventionally raised heifers. In that study, heifers on high energy diets had similar live weights 10 days before calving and lower whither heights and lower postpartum live weights. The milk production of the heifers on an accelerated growth rate had lower milk fat and milk protein yields. In contrast, the heifers with delayed breeding had higher body condition scores and a greater incidence of dystocia, but no negative effects on milk production (Hoffman *et al*., 1996). Krpálková *et al*. (2014) found that conception at first service and overall services for cows that calved down late as heifers, i.e. after 800 days (26.6 months) were higher (P<0.05) in comparison to heifers that calved down earlier.

Van Amburgh (1998) reported that heifers growing at an average daily gain (ADG) of 0.8 and 1 kg per day tended to have a six and 23 % higher pregnancy rate than heifers fed to grow at 0.6 kg per day, however, the group of heifers with the targeted ADG of 1 kg/day had a 5% reduction (P<0.05) in milk yield when compared to the 0.6 kg ADG group. Krpálková *et al*. (2014) found that although the total cost per calf at 6 months of age was lowest for heifers that calved at ≤ 24 months, this target was firstly very difficult to reach as it requires a ADG of between 0.7 and 0.8 kg /day while these heifers had the lowest fertility (P<0.05). The heifers that grew at approximately 700 to 799 g/day, and calved down at between 24 and 25 months of age had the highest milk yield (P<0.05) and proved to be the most profitable (Krpálková *et al*., 2014). The body weight and body condition score, however, had a larger influence on the variation in milk production than the pre-pubertal growth, and the conclusion was that a post calving body weight of 82 to 90% of mature size would optimize first lactation milk (P<0.05. Van Amburgh (1998) indicated that the correct live weight at first calving had the highest priority in ensuring good subsequent milk production.

The estimated live weight and height of heifers determined from height at withers and heart girth were found to be correlated with herd average milk production and age at first calving (Heinrichs & Hargrove, 1987). Heinrichs *et al*. (1992) investigated the use of body measurements to estimate body weight. The equation for determining body weight from heart girth is: $BW = 102.71 – 2.876x + 0.02655x^2$. Wither height can also be used to estimate body weight with the following equation: $BW = 632.13 – 16.837x + 0.11989x^2$, as adapted from Heinrichs *et* al. (1992) in James (2001), with x being the heart girth (cm) and wither height (cm) of the heifer, respectively.

Blöttner *et al*. (2011) found that the birth weight of calves sired by Holstein bulls on Brown Swiss x Holstein first lactation cows did not differ significantly from that of calves sired by Holstein bulls on Holstein cows. However, at second and third parity the calves of the Brown Swiss x Holstein cows were sired by Fleckvieh bulls, and these calves were significantly heavier (P<0.05) than the calves of Holstein sires on Holstein cows. However, the Brown Swiss x Holstein cows did not differ for calving difficulty or stillbirths from the Holstein cows, whatever the parity, despite having heavier calves when inseminated with Fleckvieh bulls. Brown Swiss x Holstein cows had significantly higher body weight (P<0.05) than their purebred Holstein contemporaries during first (621 kg vs. 594 kg) and second (678 kg vs. 656 kg) lactation (Blöttner *et al*., 2011). They were also found to have significantly thicker backfat (P<0.05) than purebred Holsteins in their first lactation, and they had wider chests than the Holstein cows (48 cm vs. 46 cm) (Blöttner *et al*., 2011).

The objective of the study was to compare the live weight and body size with regards to girth circumference (GC) and shoulder height (SH) of Holstein (H) and Fleckvieh x Holstein (FxH) heifers.

6.2 Materials and methods

6.2.1 Site description:

The study was conducted at the Elsenburg Research Farm, approximately 16 km from Stellenbosch in the Western Cape Province of South Africa. The farm is located at 33° 50' 33" S and 18° 49' 49" N. The area is characterised by a Mediterranean type climate with cool wet winters and warm dry summers. The long term average rainfall for the Stellenbosch area at different sites varies between about 550 and 960 mm/year (Carey *et* al., 2008). Most rainfall occurs mainly during the winter from May to September.

6.2.2 Experimental animals:

For the study 24 H and 24 FxH heifers were purchased from a commercial dairy farm over a period of about three months. Heifers included in the study were the youngest ones at the pick-up date. The goal was to obtain the calves within five days from birth. This resulted in a random selection of heifers. Subsequently, heifers born from these original animals were later included in the trial to ensure a sufficient number of experimental animals within each genotype.

At the home-farm colostrum was fed to calves until five days of age. Calves was transported to Elsenburg and put into individual pens. On arrival they received pre-heated colostrum collected from cows that had recently calved down in the Elsenburg herd. Calves then received colostrum for another five days and thereafter full cream milk at 5% of body weight (or approximately two litres of milk at each feeding) twice a day until weaning at six weeks of age.

A calf starter meal containing 18% CP was provided *ad libitum* from seven days of age until two months of age. After this period, a growth meal containing 15% CP was provided *ad libitum* until six months of age. From six months of age a growth meal containing 13% CP was provided until the calves were approximately 12 months old. At about 13 months of age heifers were put in service group where they were observed for heat detection. After being confirmed pregnant heifers were put with the dry cows on kikuyu pasture until about three weeks before their expected calving dates. They were then put with the steam-up being fed a pre-calving steam-up concentrate.

Body size measurements were recorded once a month. A single time measurement was used, i.e. all heifers in different age groups were measured on the same day. For girth circumference (GC), a non-stretch measuring tape, placed around the chest behind the front legs and shoulder of the heifer, was used. Shoulder height (SH) was measured with an adjustable ruler set against the side of an animal crush.

6.2.3 Data collection

The birth weight of heifers, as well as their monthly live weights until first calving was recorded. This was combined with their age (in days) at each weighing. The age at first calving as well as the live weight at first calving was recorded. The girth circumference and shoulder heights of heifers were also recorded monthly until first calving.

6.2.4 Statistical analysis

The data were analysed using PROC GLM procedures from SAS (2009). The effects of genotype on birth weight, calving weight, average daily gain and age at first calving were analysed using ANOVA. A linear regression was fitted to obtain individual ADG’s for use in an Ancova, with the intercept as a covariant. Repeated records were considered as uncorrelated to meet the assumptions for ANOVA. Least square means were calculated for each effect, where they separated using PDIFF STDERR of SAS (2009).

The model used was $Y_i = \mu + B_i + e_i$

Where:

Y_i = Birth weight, Calving weight, Average Daily Gain and age at first calving.

μ = population mean

B_i = fixed effect of genotype (I = Holsteins, Fleckvieh x Holsteins)

e_{ij} = random error

The von Bertalanffy growth function was fitted to each animal's girth circumference and shoulder height records on age (in days) at each measuring event separately. Regression parameters obtained were used for an analysis of variance comparing regression parameters for genotypes.

6.3 Results and discussions

6.3.1 Weight at birth and at calving, and average daily gain (ADG).

Growth parameters of H and FxH heifers from birth to first calving are presented in Table 6.1. It is unexpected that the birth weights of FxH and H heifers did not differ (P>0.05). The birth weight of heifers is affected by age of the dam increasing with lactation number.

Table 6.1. The mean (± s.e.) birth weight, average daily gain, live weight at first calving and age at first calving of Holstein and Fleckvieh x Holstein heifers

Parameters	Holstein	Fleckvieh x Holstein	P
Number of heifers	67	80	-
Birth weight (kg)	37.4 ± 0.71	37.7 ± 0.65	0.74
Average daily gain (kg)	0.696^b ± 0.017	0.813^a ± 0.021	0.001
Live weight at first calving (kg)	586 ± 11	611 ± 11	0.12

^{a,b}Values in the same row with different superscripts differ at P<0.05

As expected, the average daily gain (ADG) of FxH heifers was higher (P<0.01) than that of H heifers. This could be attributed to the beef type characteristics of the Fleckvieh breed being a dual-purpose type.

The higher growth rate and live weight at first calving of FxH heifers (P>0.05) did not impact negatively on age at first calving. The growth rate and age of first calving of H and FxH heifers was similar to results showed by Krpálková *et al*. (2014) for H and FxH heifers as 0.700 to 0.799 kg per day and 26.4 ± 0.37 and 26.5 ± 0,38 months.

6.3.2 Body size of Holstein and Fleckvieh x Holstein heifers

The average girth circumference (GC) and shoulder height (SH) at birth of FxH and H heifers differed (*P*<0.01), being 77.4±7.4 vs.73.5±9.5 and 70.7±6.4 vs. 64.5±9.8 cm respectively. Maximum GC and SH did not differ (*P*>0.01) between genotypes, being 217.2±16.3 vs. 212.6±12.4 and 143.3±6.7 vs.142.7±4.5 cm, respectively. Shoulder height growth rate (cm/day) differed (*P*<0.01) between genotypes, being -0.0032±0.085 vs. -0.0036±0.001, but GC growth rate did not differ (*P*>0.05), being -0.0026±0.0007 vs. -0.0028±0.0007. The larger size of FxH heifers at birth was maintained while the GC growth rate did not differ (P>0.05) between genotypes. The growth curves for GC and SH of H and FxH heifers did not differ (P>0.05) which is unexpected as the FxH heifers were perceived to be bigger than H heifers. The shoulder height and girth circumference differences between FxH and H heifers are presented in Figures 6.1 and 6.2.

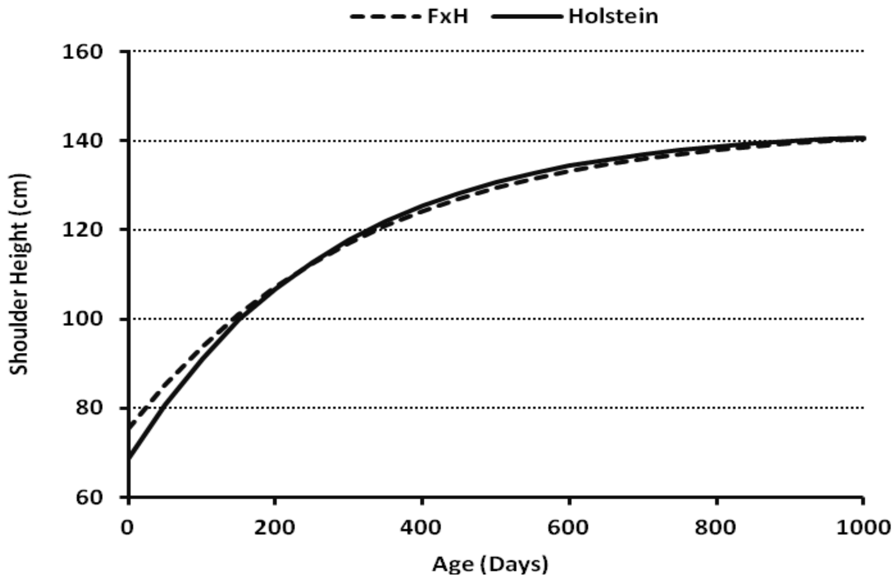

Figure 6.1 The shoulder height for Holstein and Fleckvieh x Holstein (FxH) heifers against age in days

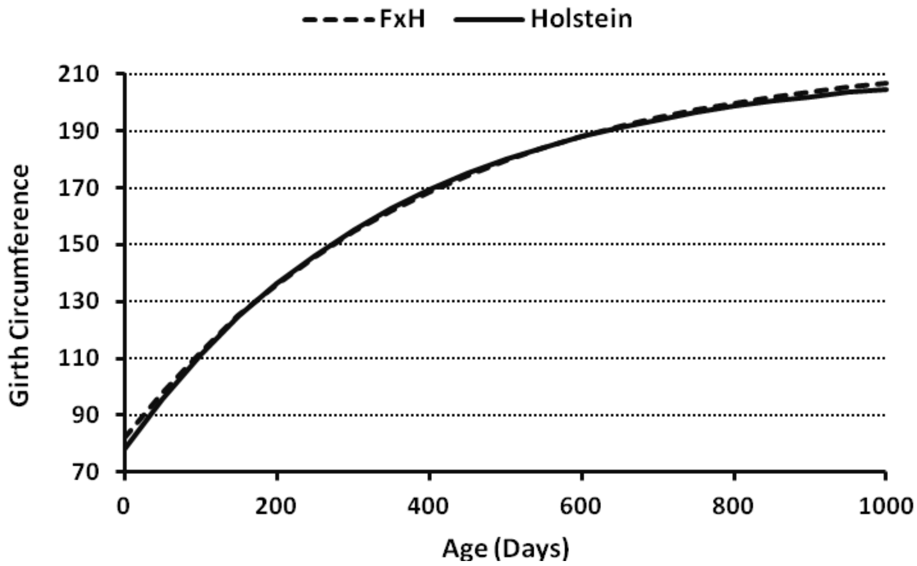

Figure 6.2 The girth circumference for Holstein and Fleckvieh x Holstein (FxH) heifers against age in days

Ozkaya & Bozkurt (2008) found differences in the wither height (P<0.05) of Holstein and Brown Swiss slaughter cattle being 123.45±1.4 and 132.60±0.66 cm, respectively. This study, however, does not indicate any differences (P>0.05) in the wither height or the girth circumference of H and FxH heifers.

6.4 Conclusion

The results of the trial indicated that the F_1 FxH heifers had a higher average daily gain (P<0.05) than H heifers, but when all crossbred heifers of later generations were also included in the analysis, the difference was not significant (P>0.05). This is probably due to a large variation among heifers within each genotype group which probably accounts for the lack of significant difference in the age at first calving. The birth weights of heifers of the two genotypes did not differ (P>0.05) significantly, and though the live weight at first calving tended to be higher (P=0.12) in FxH heifers in comparison to H heifers. The growth traits of shoulder height and girth circumference were very similar for the FxH and H heifers, indicating that these traits can be used to monitor the growth of the heifers, regardless of genotype. More research will, however, have to be done to ensure that these traits can be used reliably for optimum, and not maximum growth, ensuring the highest profitability for a dairy herd by ensuring that the heifers grow at the correct rate for maximum milk production as well as good fertility.

6.5 References

Blöttner, S., Heins, B.J., Wensch-Dorendorf, M., Hansen, L.B., & Swalve, H.H., 2011. Brown Swiss x Holstein crossbreds compared with pure Holsteins for calving traits, body weight, backfat thickness, fertility and body measurements. J. Dairy Sci. 94: 1058 – 1068.

Carey, V.A., Saayman, D., Archer, E., Barbeau, G. & Wallace, M., 2008. Viticulture terroirs in Stellenbosch, South Africa. I. The identification of natural terroir units. J. Int. Sci. Vigne Vin. 42: 169 – 183.

Heinrichs, A.J. & Hargrove, G.L., 1987. Standards of weight and height for Holstein heifers. J. Dairy Sci. 70 (3): 653 – 660.

Heinrichs, A.J., Rogers, G.W. & Cooper, J.B., 1992. Predicting body weight and wither height in Holstein heifers using body measurements. J. Dairy Sci. 75: 3576 – 3581.

Hoffman, P.C., Brehm, N.M., Price, S.G. & Prill-Adams, A., 1996. Effect of accelerated postpubertal growth and early calving on lactation performance of primiparous Holstein heifers. J. Dairy Sci. 79: 2024 – 2031.

James, R.E., 2001. Growth standards and nutrient requirements for dDairy heifers – weaning to calving. Advances in Dairy Technology 13: 63 – 77.

Krpálková, L., Cabrera, V.E., Kvapilik, J., Burdych, J., & Crump, P., 2014. Associations between age at first calving, rearing average daily weight gain, herd milk yield and dairy herd production, reproduction and profitability. J. Dairy Sci. 97: 6573 – 6582.

Ozkaya, S. & Bozkurt, Y., 2008. The relationship of parameters of body measures and body weight by using digital image analysis of pre-slaughter cattle. Arch. Tierz., Dummerstorf 51(2): 120 – 128.

Statistical Analysis systems, 2009. SAS User's guide. SAS Institute Inc., Cary, N.C. USA.

Van Amburgh, M.E., Galton, D.M., Bauman, D.E., Everett, R.W., Fox, D.G., Chase, L.E. & Erb, H.N., 1998. Effects of three prepubertal body growth rates on performance of Holstein heifers during first lactation. J. Dairy Sci. 81: 527 – 538.

Chapter 7

General conclusion and recommendations

Dairy farmers often experience an income-production cost disparity making it difficult to survive economically. A major indirect problem in the dairy industry is the survival of dairy cows to at least fourth of fifth lactation when milk yield efficiency is at its highest. This is mainly because of fertility problems resulting in extended lactations or long dry periods or culling of cows for not becoming pregnant again. Extended lactations result in cows being milked longer than the standard 300-day lactation period. The milk yield of cows then is usually low. When a large proportion of cows in the herd are in late lactation, i.e. past 280 days, total herd milk yield is low as well as average milk yield per cow.

The milk production performance of Holstein cows has shown a large increase over the past 30 years. Poor fertility in dairy cows has been linked to this increase in milk yield with cows not getting pregnant soon after calving probably because of a negative energy balance. Because cows are culled when not becoming pregnant again, their longevity is affected negatively. High culling rates increases the number of replacement heifers in dairy herds increasing the cost of production. Improving fertility in dairy cows genetically is difficult as dairy cows have long generation intervals while the heritability of fertility traits is generally low. Crossbreeding has been shown to have a positive effect on low heritable traits like fertility and longevity. A number of studies have shown positive results with regards to fertility using sire breeds such as Normande, Montbéliarde and Scandinavian Red on Holstein cows. Fleckvieh and Montbéliarde are both Simmental derived breeds from Germany and France respectively.

The aim of the study was to determine the effect of crossbreeding using Fleckvieh (F) sires on Holstein (H) cows comparing the milk production and reproductive performance of Fleckvieh x Holstein (FxH) and H cows in an intensive feeding system. The growth rate of FxH and H heifers, veal calves and steers are also compared between breeds.

Milk production parameters of FxH and H cows did not differ ($P>0.05$) although the fat and protein percentages in milk was higher ($P<0.05$) in FxH cows in comparison to H cows. Production parameters of cows in both genotypes increased ($P<0.05$) from first to second lactation after which lactation milk yield declined to fourth lactation although still exceeding first lactation milk yields.

Although the fertility of FxH and H heifers did not differ ($P>0.05$) resulting in a similar age at first calving, differences were found in the fertility traits of FxH and H cows. Fleckvieh x Holstein cows had fewer ($P<0.05$) days from calving to first service than H cows, being 86.2±5.3 and 104.7±5.0 days respectively. Similarly, the interval from calving to conception was also shorter ($P=0.07$) for FxH cows in comparison to H cows, being 135.3±7.1 vs. 153.1±6.8 days, respectively. This is further emphasised by a larger proportion of FxH cows being confirmed pregnant within 100 days post partum, 48±6 vs. 37±6% in comparison to H cows. These results seem to indicate a better fertility in FxH cows in comparison to H cows. Getting cows in calf earlier is of great value to a dairy farmer, as this limits the unproductive interval of cows while reducing the risk of being culled for poor fertility.

Although expecting a higher beef income from FxH veal calves and steers, live weights at marketing, for both veal and beef production systems did not differ between genotypes probably indicating the original dual-purpose characteristics of the Dutch-type Friesians from which Holsteins were derived. However, the growth curve of H and FxH steers showed a divergence from about 15 months of age probably indicating that FxH steers should have been marketed at a later age probably because of being a later maturing breed.

Similarly, the growth rate of H and FxH heifers did not differ reaching similar (P>0.05) live weights at first calving. Body size traits, i.e. girth circumference and shoulder height, similarly did not differ (P>0.05) between genotypes. Although not directly measured, anecdotal evidence seems to indicate that FxH heifers had a wider body width than H heifers. If this is indeed the case translating the wider body width to lactating cows, it would affect housing requirements of cows as well as the space required in specifically herringbone milking parlours.

Although not directly recorded, it seemed that the cull rate of H and FxH herds differed as there were a large number of FxH cows and heifers than H cows and heifers at the end of the trial. At the start of the trial, 23 FxH and 22 H first lactation cows were included in the study. The feeding and reproductive management of the two herds was similar. The progeny of the original cows were included in the two herds. Cows were culled for normal reasons, i.e. not becoming pregnant, recurring mastitis cases, injuries or death. Bull calves were reared for either veal production or as beef at 18 months of age. Heifers were reared to be eventually included in the two herds. At the close of the study, the FxH herd consisted of 70 animals, 34 heifers and 36 cows, while the H herd consisted of 30 animals, 15 heifers and 15 cows. This means that while the FxH herd had increased in size by 9.4% per year, the H herd had declined by 5.3% per year. This difference in internal herd growth between the two breeds using a standard herd size of 25 cows at the start of the trial and a value of R8000 per cow would amount to R560 000 over the six year period in favour of the FxH herd. The difference in the herd numbers is most probably related to a better survival of crossbred cows in comparison to purebred cows.

This study has shown clear production differences between FxH and H cows. Although milk, fat and protein production was similar, fat and protein percentages in the milk of FxH cows were higher than in H cows. Similarly, some fertility parameters also favoured FxH cows in comparison to H cows. Further studies are required to determine the effect of using a dual-purpose breed on the lifetime production and productive life efficiencies of FxH cows in comparison to purebred Holsteins. The optimum marketing age of FxH steers should be established as it would probably be later than 18 months of age to accommodate the late maturing characteristics of the Fleckvieh breed. Different diets should be compared in beef production systems to utilize the beef potential of the Fleckvieh breed. An expected higher growth rate in heifers could possibly result in an earlier age at first calving. This would require using diets containing different energy levels.

As the survival of crossbred cows seems to be better than in purebred cows, crossbreeding studies should be done over a longer term than the present study which was conducted over an eight year period. This would give a better indication of the longevity of crossbred cows vs. purebred cows as well as the production potential of older cows in comparison to first to fourth lactation cows. The effect of a rotational crossbreeding system should be evaluated as well as it remains an open question which breed should be used on the F1 (50% Fleckvieh) cows. Studies comparing crossbred cows to purebred cows should also be conducted under poor feeding conditions to provide guidelines for resource poor farmers. Genotype differences should also be evaluated on a genomic level.

Studies should also include larger experimental groups to validate results quicker while an economic analysis should also be included in such studies. From research conducted in the USA crossbreeding in dairy herds seems to be increasing rather than decreasing.